Università degli Studi "G.D'Annunzio" Chieti-Pescara
Scuola superiore "G.D'Annunzio"
Dottorato di ricerca in "Progettazione ed ingegneria del sottosuolo e dell'ambiente costruito, curriculum "Building Technology and Environment", XXVIII ciclo

Universitat Politècnica de València
Escuela de doctorado
Doctorado en Arquitectura, Edificación, Urbanística y Paisaje

JOINT RESEARCH PHD THESIS

FROM POST EARTHQUAKE WASTE TO RESOURCE

PhD student: ing. Stefania De Gregorio

Thesis supervisor: **Prof.ssa M. C. Forlani**
Università degli Studi "G.D'Annunzio" Chieti-Pescara
Thesis supervisor: **Prof. L. Palmero**
Universitat Politècnica de València
Co-supervisor: **Prof. P. De Berardinis**
Università degli Studi dell'Aquila

April 2016

JOINT RESEARCH DOCTORAL THESIS

UNIVERSITA' DEGLI STUDI "G. d'Annunzio"Chieti-Pescara
SCUOLA SUPERIORE "G. d'Annunzio"
Dottorato di ricerca in
"Progettazione ed Ingegneria del Sottosuolo e dell'Ambiente costruito"
curriculum "Building Technology and Environment"
Ciclo XXVIII ciclo
Dipartimento di Architettura
Settore scientifico disciplinare ICAR/12

UNIVERSITAT POLITÈCNICA DE VALÈNCIA
ESCUELA DE DOCTORADO
Doctorado en Arquitectura, Edificación, Urbanística y Paisaje

Title:

FROM POST EARTHQUAKE WASTE TO RESOURCE

PhD student
Ing. Stefania De Gregorio

Coordinator Ud'A
Prof.Nicola Sciarra

Thesis supervisor Ud'A
Prof. Maria Cristina Forlani

Thesis supervisor UPV
Prof. Luis Palmero

Co-supervisor
Prof. Pierluigi De Berardinis

Academic years 2013/2015
Discussion: April 2016

A mia madre, mio padre e mio fratello Fabrizio

"There is nothing mysterious in the process of innovation. What is needed is courage, attention and care to detail and expecially, to believe in it and begin."

(Peter Rice)

The research was funded by the "Fondazione Ferdinando Filauro"
Università degli Studi de L'Aquila

Index

PHASE 3_ Specific analytical learning phase. Characterization of waste elements arising from the selective demolition of safety systems in L'Aquila.

PHASE 4_ Research processing fhase. Optimization of the reuse of materials resulting from selective demolition of safety systems in L'Aquila.

ABSTRACT_en

The international debate on the environmental crisis, known since the 70's, pushes to review priorities in light of today's time to safeguard the future.
The theory of the bio-economy holds the logical assumption that the opportunity to use a material is established by the impact that it has on the balance of the environment. It is necessary to pay attention to the monetary compensation between inflows and outflows, creating closed loops, where the "wastes" of a loop feed another cycle. In this regard, the problem of waste disposal takes on a great importance, especially from the construction sector.
At the same time, it is necessary to revamp the Italian architectural heritage (especially post-war) because of the bad state of conservation and obsolescence in the components of the construction system. There is also the additional requisite to respond to changing needs at the time of construction.
The research identifies the implementation of regeneration building through the transformation of waste into resources for the area. The local dimension combined with the waste reduction are guarantors for the sustainability of the regeneration process. This progression starts from the territory and reaches the building.
The study of regulatory laws and best practices in the field of construction make it possible to identify effective ways of reusing components.
In addition, the methods, tools and techniques of demolition are analysed to ensure the uniformity of the merceologic fraction and the integrity of the elements. The analysis of selective demolition cases allows us to identify the possible ways to organise and manage demolition phases aimed at achieving environmental and economic benefits. Returns are earned by operating at the regional level, which results in urban regeneration. This progressive development creates a sustainable local supply chain based on closed cycles of matter.
In the goal to promote the exploitation of the residual performances of materials that derive from selective demolitions, such as wood and steel, methodological and operational processes aimed at maximizing their reuse are further explained.
In regard to wooden elements, the methodological-operative lines take into account degradation, potential treatments (preventive and curative), durability depending on the species and the climatic conditions, in which the elements are placed and the minimum requirements for structural reuse. For the latter, the carried out lab tests demonstrate the inadequacy of visual grading in the definition of the mechanical properties of the elements under investigation. The visual rating, albeit cautionary, does not always provide results that are adequate with the real properties of the element. This often results in an underestimation of the mechanical properties. The proposed process takes into account the information generated from the first lifecycle in order to exploit the true performance of the element and not the supposed. This ensures the environmental sustainability of the reuse process. Depending on specific characteristics of the element and suitable treatments, levels of reuse are defined. The process allows the technician to evaluate the conditions and actual requirements at the time of reuse and the possible modes of reuse. It starts from a maximum threshold of exploitation of the element until it reaches a minimum threshold, which coincides with the landfilling.
As for the steel elements, the international standards currently in force are analysed and the methodological-operative process specific for reuse is examined. Even in this case, the optimization of reuse involves the analysis of information obtained from previous life cycles, such as the analysis of the level of steel corrosion and degradation of its protection treatment. The identification of possible treatments can be performed according to the class of environmental corrosion and a precise estimation of the durability, in order to program maintenance.
The developed theories have been tested in the territory of L'Aquila, Italy. The city was severely damaged by the earthquake on the 6th of April, 2009. The reconstruction is an opportunity for the regeneration and development of the whole territory; however, it has many logistical, environmental and economical problems.
In fact, the need to quickly overcome the state of emergency created by the earthquake and act in large scale on the entire territory of L'Aquila have produced functional solutions exclusively for the occurring moment. The restoration of the roads and the preservation of buildings necessitated the construction of safety systems. When reconstruction operations of a building begin, safety systems should be gradually dismantled. At present, end-life scenarios are not programmed and the materials that constitute the safety systems are temporarily stored or transported to the landfill. The enormous quantity of waste, mainly steel and wood components, results in economic and environmental damage, along with logistical disruptions.
The research defines methodological-operative lines to reuse and recycle the materials that make up the safety systems, identify ways to pursue the optimization and sustainability of the rebuilding process and develop short chains of secondary raw materials to promote new local economies.
Specifically, preliminary analysis consisted of bibliographic research and standards in carrying out several inspections in the seismic crater aimed at identifying modes of securing installed safety systems and components.
With respect to the collected data, starting from the obligation of the laws and the optimization methods of the durability of the steel and wood in the reuse, it has defined a process for the specific reuse in the seismic crater. Two lines of research developed from the data, and they are detailed below.

- Endogenous reuse: the materials that are derived from the dismantling of safety systems are immediately reused in sites for the construction of tempo-

rary buildings, i.e. construction site offices, changing rooms, refectories, toilets, etc. Temporary endogenous reuse is included in the reconstruction project with the matching function of structural or technological adjustment. Endogenous permanent reuse occurs through the improvement for the installations or redefinition of the internal space.
- Exogenous reuse: the materials that are derived from the dismantling of safety systems, are reused in neighbouring reconstruction sites within a radius of 100 km. The materials can also be used for the construction of temporary structures designed to accommodate the functions related to the community, such as school, offices, residences, etc.

Both lines of research have been supported by design experiments, in particular regarding:
- the study of selective demolition of safety systems at the Civic Museum of Santa Maria dei Raccomandati. The experiment centred on the residual performance and the potential reuse of materials and components derived from it. The definition of a common construction site area where the site services are built with material produced from selective demolitions (offices, toilets, changing rooms, etc.) in the nearby Santa Maria Paganica square for simultaneous and programmed use by companies operating in the reconstruction was also created;
- the definition of the processing steps necessary for the renovation of a post-war building and the consideration needed to carry out the work for floors and the shelter of users in temporary sustainable modules with high energy efficiency whose components are derived from the dismantling of safety systems.

Finally, through the use of the prices present in the Region Abruzzo Price List and by using the data previously obtained, a spread sheet for the assessment of the economic and environmental gain resulting from the reuse by businesses and public administrations was created.
The research was used to define and develop sustainable methods for regeneration building, which also apply to the reconstruction of L'Aquila, to promote local resources and to resolve logistical, economical and environmental issues related to this process. This transforms the lack of programming the end-of-life scenarios of materials resulting from the dismantling of the safety systems into an opportunity for innovation.

ABSTRACT_it

Il dibattito internazionale sulla crisi ambientale, sviluppatosi a partire dagli anni Settanta, spinge a rivedere le priorità del tempo odierno per salvaguardare il futuro.

La teoria della bioeconomia trova un'evoluzione logica nell'assunto che l'opportunità di utilizzo di un materiale venga stabilita dall'impatto che esso ha sull'equilibrio dell'ambiente. Bisogna, dunque, porre attenzione alla compensazione tra flussi in entrata e in uscita, generando cicli chiusi, dove gli "scarti" di un ciclo ne alimentano un altro. A riguardo assume una notevole rilevanza la problematica relativa allo smaltimento dei rifiuti, in particolare quando essi derivano dal settore delle costruzioni.

Parallelamente esiste la necessità di riqualificare il patrimonio edile italiano (soprattutto post-bellico) a causa del cattivo stato conservativo e dell'obsolescenza dei componenti del sistema costruttivo, ma anche della necessità di rispondere ad esigenze mutate rispetto al momento della costruzione.

La ricerca individua le modalità di attuazione della rigenerazione edilizia attraverso la trasformazione degli scarti in risorse per il territorio. La dimensione locale unita alla riduzione dei rifiuti sono garanti della sostenibilità del processo di rigenerazione, che parte dal territorio per arrivare all'edificio. Lo studio normativo e delle buone pratiche in ambito edile hanno consentito di individuare le modalità di riuso dei componenti. Inoltre, sono stati analizzati i metodi, gli strumenti e le tecniche di demolizione tali da garantire l'uniformità della frazione merceologica e l'integrità degli elementi. L'analisi di casi di demolizione selettiva ha consentito di individuare le possibili modalità di organizzazione e gestione delle fasi operative finalizzate al raggiungimento della convenienza economica ed ambientale. Queste ultime sono condizionate dall'operare a livello territoriale, che provoca, nel mentre della rigenerazione urbana, un progressivo sviluppo della filiera sostenibile locale.

Con l'obiettivo di promuovere lo sfruttamento delle prestazioni residue di materiali che derivano dalle demolizioni selettive, per il legno e per l'acciaio sono stati elaborati iter metodologici-operativi volti all'ottimizzazione del loro riuso.

Per ciò che concerne gli elementi in legno, le linee metodologiche-operative prendono in considerazione il degrado, i trattamenti potenziali sia di tipo curativo che preventivo, la durabilità in funzione della specie e della condizioni climatiche in cui gli elementi vengono posti in opera e i requisiti minimi per il riuso strutturale. Per quest'ultimo, le prove di laboratorio effettuate hanno dimostrato l'inadeguatezza della classificazione visuale nella definizione delle caratteristiche meccaniche dell'elemento indagato, quando si tratta di elementi usati. La classificazione visuale, seppur sempre cautelativa, non fornisce risultati pienamente rispondenti con le proprietà reali dell'elemento, causando spesso una sottostima delle proprietà meccaniche. L'iter proposto prende in considerazione le informazioni derivanti dal primo ciclo di vita in modo da sfruttare le reali prestazioni dell'elemento e non quelle supposte, garantendo la sostenibilità ambientale del processo di riuso. In funzione delle caratteristiche proprie dell'elemento e dei trattamenti applicabili, sono stati definiti specifici livelli di riuso, che consentono al tecnico di valutare le possibili modalità di riuso, da una soglia massima di sfruttamento delle potenzialità dell'elemento fino ad una soglia minima, coincidente con il conferimento a discarica.

Per ciò che concerne gli elementi in acciaio sono state messe a sistema le normative internazionali vigenti ed è stato ricavato un iter metodologico-operativo specifico per il riuso. Anche in tale caso, l'ottimizzazione del riuso coinvolge l'analisi delle informazioni ricavabili dai cicli di vita precedenti, l'analisi del livello di corrosione dell'acciaio e del degrado del trattamento di protezione presente, l'individuazione dei trattamenti effettuabili e delle prestazioni raggiungibili in funzione della classe di corrosività ambientale e una precisa stima della durabilità presunta, onde programmare l'effettuazione di interventi di manutenzione.

Le teorie elaborate sono state sperimentate nel territorio de L'Aquila (Italia), gravemente provato dal terremoto del 6 aprile 2009. La ricostruzione è, infatti, un'opportunità di rigenerazione e sviluppo dell'intero territorio, ma allo stato attuale presenta numerose problematiche logistiche, ambientali ed economiche.

Infatti, la necessità di superare con rapidità lo stato di emergenza generato dal terremoto e di agire a larga scala hanno prodotto soluzioni funzionali solo ed esclusivamente per il momento contingente e non ragionate in funzione degli sviluppi futuri del territorio. Il ripristino della viabilità stradale e la salvaguardia dei fabbricati hanno necessitato l'esecuzione di operazioni di messa in sicurezza. Nel momento in cui iniziano le operazioni di ricostruzione su un fabbricato tali sistemi devono essere smontati.

Allo stato attuale non sono stati programmati scenari di fine vita e i materiali che costituiscono i sistemi di messa in sicurezza confluiscono, pertanto, in deposito temporaneo o a discarica. Data l'enorme quantità di rifiuti (prevalentemente componenti in acciaio e legno) ne conseguono danni di tipo economico e ambientale oltre che disagi di tipo logistico.

Il progetto di ricerca definisce linee metodologico-operative di riutilizzo/recupero dei materiali che costituiscono i sistemi di messa in sicurezza e individua le modalità per perseguire l'ottimizzazione e la sostenibilità del processo di ricostruzione e lo sviluppo di filiere corte di materie prime seconde, tali da promuovere nuove economie locali.

Nello specifico, le analisi preliminari sono consistite in ricerche bibliografiche e normative e nell'effettuazione di numerosi sopralluoghi nel cratere sismico volti ad individuare le modalità di messa in sicurezza, i sistemi utilizzati e i componenti che li costituiscono. Rispetto ai dati risultanti, alla normativa e alle modalità di ottimizzazione della durabilità dell'acciaio e del legno come precedentemente approfondite, è stato definito un iter di riutilizzo specifico per il cratere sismico, sviluppando due linee di ricerca:

- riutilizzo endogeno: i materiali che derivano dallo smontaggio dei sistemi di messa in sicurezza vengono immediatamente riutilizzati all'interno del cantiere per la costruzione di opere temporanee, ovvero i servizi di cantiere come uffici, spogliatoi, servizi igienici, etc. (riutilizzo endogeno temporaneo) o vengono inseriti nel progetto di ricostruzione con funzione di adeguamento/miglioramento strutturale, impiantistico, tecnologico o per la ridefinizione della spazialità interna (riutilizzo endogeno permanente);
- riutilizzo esogeno: i materiali che derivano dallo smontaggio dei sistemi di messa in sicurezza vengono riutilizzati in cantieri di ricostruzione limitrofi (nel raggio di 100 Km) o per la costruzione di strutture temporanee atte ad ospitare le funzioni legate alla collettività (scuola, uffici, residenze, etc.).

Entrambe le linee di ricerca sono state supportate da sperimentazioni progettuali, riguardanti nello specifico:

- lo studio delle modalità di demolizione selettiva dei sistemi di messa in sicurezza del Museo Civico di Santa Maria dei Raccomandati e lo studio delle prestazioni residue e del potenziale di riuso dei materiali/componenti da essa derivanti e la definizione di un'area comune di cantiere i cui apprestamenti sono costruiti con i materiali derivanti dalle limitrofe demolizioni selettive (uffici, servizi igienici, spogliatoi, etc.) nella limitrofa Piazza di Santa Maria Paganica per l'uso contemporaneo e programmato da parte delle imprese che operano nella ricostruzione;
- la definizione delle fasi di lavorazione necessarie per il recupero di un fabbricato appartenente al patrimonio immobiliare post-bellico considerando l'effettuazione di lavorazioni per piani e il ricovero degli utilizzatori in moduli temporanei sostenibili ad alta efficienza energetica, i cui componenti derivano dallo smontaggio dei sistemi di messa in sicurezza.

Infine, attraverso l'utilizzo dei prezzi presenti nel Prezzario della Regione Abruzzo e utilizzando i dati precedentemente ricavati, è stato realizzato un foglio di calcolo per la valutazione del guadagno economico ed ambientale derivante dal riutilizzo ad opera delle imprese e delle Pubbliche Amministrazioni.

La ricerca ha consentito di definire modalità di rigenerazione edilizia sostenibile applicabili anche alla ricostruzione attualmente in corso nel territorio de L'Aquila, volte a promuovere le risorse del territorio e al contempo a risolvere le problematiche logistiche, economiche ed ambientali legate con tale processo, trasformando la mancanza di programmazione degli scenari di fine vita dei materiali derivanti dallo smontaggio dei sistemi di messa in sicurezza in un'opportunità di innovazione.

ABSTRACT_esp

El debate internacional sobre la crisis ambiental, desarrollada desde los años setenta, anima a revisar las prioridades de la época actual para salvaguardar el futuro.
La teoría de la bio-economía encuentra una evolución lógica en cuanto a la oportunidad de utilizar un material y el impacto que tiene sobre el equilibrio del medio ambiente. Por tanto, debemos prestar atención a la compensación entre los flujos de entrada y salida, generando ciclos cerrados, donde los "residuos" de un ciclo alimenten a otro ciclo. En este sentido tiene una gran importancia el problema de la eliminación de residuos, especialmente cuando provienen del sector de la construcción.
Paralelamente existe la necesidad de renovar el patrimonio arquitectónico italiano, (especialmente aquel construido después de la guerra), debido no solo al mal estado de conservación y obsolescencia de los componentes del sistema de construcción empleado, sino también de dar respuesta a las cambiantes necesidades respecto al momento de su construcción.
La investigación identifica las modalidades de ejecución en cuanto a la regeneración de las construcciones a través de la transformación de los residuos en recursos medioambientales o sostenibles. La dimensión local combinada con la reducción de los residuos son garantes de la sostenibilidad del proceso de regeneración, que comienza desde sus inicios hasta llegar al edificio.
El estudio de las normas y de las buenas prácticas en el campo de la construcción, ha hecho posible determinar modalidades de actuación para la reutilización de componentes.
Además, se han analizado los métodos, herramientas y técnicas para la demolición garantizando la uniformidad de los materiales y la integridad de los elementos. El análisis de los casos de demolición selectiva ha identificado los posibles modos de organización y gestión de los pasos operativos encaminados a lograr el beneficio ambiental. Estos están condicionados por su gestión a nivel local, lo que hace que, mientras se efectúa la regeneración urbana, se desarrolle progresivamente la cadena de suministro local sostenible.
Con el objetivo de promover la explotación de las prestaciones residuales de los materiales resultantes de la demolición selectiva, en el caso de la madera y el acero fueron elaborados procesos metodológicos-operativos para la optimización de su reutilización.
Por lo que concierne a los elementos de madera, las líneas metodológicas-operativas tienen en cuenta la degradación, los tratamientos potenciales de tipo curativo y preventivo, la durabilidad respecto a la especie en cuestión y a las condiciones climáticas en las que este material se coloca en la construcción, así como los requisitos mínimos para su reutilización estructural. En este último caso, las pruebas de laboratorio realizadas han demostrado la inadecuación de la clasificación visual en la definición de las propiedades mecánicas del elemento bajo investigación, cuando los elementos ya han sido usados o provienen de la recuperación. La clasificación visual, aunque siempre segura, no proporciona resultados coincidentes con las propiedades reales del elemento, causando a menudo una subestimación de las propiedades mecánicas. El proceso propuesto tiene en cuenta la información resultante del primer ciclo de vida para aprovechar el verdadero rendimiento del elemento y no el supuesto, asegurando la sostenibilidad ambiental del proceso de reutilización. En función de las características del elemento y de los tratamientos aplicables, se han definido los niveles específicos de reutilización, que permiten al técnico evaluar los posibles modos de re-uso, a partir de un umbral máximo de explotación del potencial del elemento hasta un umbral mínimo, que coincide con el depósito en vertederos.
En cuanto a los elementos de acero, se han puesto en correlación las normas internacionales vigentes y se ha definido un proceso metodológico-operativo específico para su reutilización. También en este caso, la optimización de reutilización implica el análisis de la información derivada de los ciclos de vida anteriores, el análisis del nivel de la corrosión y de la degradación del tratamiento de protección, la identificación de los tratamientos que pueden ser realizados y de las prestaciones alcanzables respecto a la corrosividad ambiental y una estimación precisa de la durabilidad presunta, con el fin de programar la ejecución del mantenimiento.
Las teorías desarrolladas han sido experimentadas en el territorio de L'Aquila (Italia), severamente dañado por el terremoto ocurrido el día 6 de abril de 2009. La reconstrucción es, de hecho, una oportunidad para la regeneración y el desarrollo de todo el territorio, pero en la actualidad tiene muchos problemas de orden logístico, ambiental y económico.
De hecho, la necesidad de intervención urgente creada por el terremoto y la forma de actuar a gran escala han producido soluciones funcionales exclusivamente para el momento contingente y no pensadas a la luz de los futuros desarrollos de la zona. La recuperación de la viabilidad y la preservación de los edificios han necesitado operaciones de consolidación de los edificios. Cuando comiencen las operaciones de reconstrucción del edificio, estos sistemas deben ser desmantelados. En la actualidad no han sido programados escenarios contemplen la viabilidad del final del ciclo de vida y los materiales que componen los sistemas de seguridad, por lo tanto, van a confluir en el almacenamiento o el vertedero temporal. Dada la enorme cantidad de residuos (principalmente componentes de acero y madera) resulta un daño muy importante tanto a nivel económico, como ambiental y logístico.
El proyecto de investigación define líneas metodológico-operativas para la reutilización/recuperación de los materiales que componen los sistemas de seguridad de los edificios e identifica maneras de conseguir la optimización y la sostenibilidad del proceso de reconstrucción y desarrollo de cadenas locales de materias primas secundarias, que promuevan nuevas economías.

En concreto, el análisis preliminar consistió en la investigación bibliográfica, de la normativa y en la realización de varias inspecciones en el territorio del terremoto, dirigido a identificar las modalidades de consolidación de los edificios, los sistemas constructivos instalados y los componentes que los constituyen. Comparando los datos, las normas y los métodos de optimización de la durabilidad del acero y de la madera como se detalla anteriormente, se ha definido un proceso de reutilización específico para el territorio de L'Aquila, desarrollando dos líneas de investigación:

- reutilización endógena: los materiales provenientes del desmantelamiento de los sistemas de seguridad que son inmediatamente reutilizados dentro de la obra para la edificación de construcciones temporales o servicios, como oficinas, vestuarios, aseos, etc. (reutilización endógena temporal) o se insertan en el proyecto de reconstrucción con función de ajuste/mejoría de las estructuras, de las instalaciones o de los aspectos o la redefinición del espacio interno (reutilización endógena permanente);
- reutilización exógena: los materiales que derivan del desmantelamiento de los sistemas de seguridad se reutilizan en las obras de reconstrucción vecinas (en un radio de 100 km) o para la construcción de estructuras temporales que albergan las funciones relacionadas con la comunidad (escuelas, oficinas, residencias, etc.).

Ambas líneas de investigación han sido apoyadas por experimentos de diseño, en relación en particular con:

- el estudio de los métodos de demolición selectiva de los sistemas de consolidación en el Museo Civico de Santa Maria dei Raccomandati, el estudio de las prestaciones residuales y del potencial de reutilización de los materiales/componentes que derivan de ella y la definición de un espacio común de la obra donde los servicios (oficinas, aseos, vestuarios, etc.), sean construidos con materiales procedentes de demoliciones selectivas cercanas a la vecina plaza de Santa Maria Paganica para el uso programado y simultáneo de las empresas que operan en la reconstrucción;
- la definición del procesamiento de los pasos necesarios para la renovación de un edificio perteneciente al patrimonio post-guerra, considerando la realización trabajando en cada planta singularmente y la hospitalización de los usuarios en estructuras temporales con elevada eficiencia energética, cuyos componentes se derivan del desmantelamiento de los sistemas de la seguridad.

Por último, a través de la utilización de la lista de precios de la Regione Abruzzo y el uso de los datos obtenidos previamente, ha sido elaborada una hoja de cálculo para evaluar el beneficio ambiental y económico resultante de la reutilización para las empresas y para las administraciones públicas.

La investigación ha permitido desarrollar métodos de regeneración de la construcción sostenible, que pueden ser aplicados también a la reconstrucción en curso en la zona de L'Aquila, para promover los recursos locales y al mismo tiempo para resolver los problemas logísticos, económicos y ambientales relacionados con este proceso, transformando la falta de escenarios de planificación del final del ciclo de vida de los materiales resultantes del desmantelamiento de los sistemas de seguridad en una importante oportunidad para la innovación.

ABSTRACT_val

El debat internacional sobre la crisi ambiental, desenvolupada des dels anys setanta, anima a revisar les prioritats de l'època actual per salvaguardar el futur.

La teoria de la bio-economia troba una evolució lògica quant a l'oportunitat d'utilitzar un material i l'impacte que té sobre l'equilibri del medi ambient. Per tant, hem de parar atenció a la compensació entre els fluxos d'entrada i sortida, generant cicles tancats, on els "residus" d'un cicle alimentin un altre cicle. En aquest sentit té una gran importància el problema de l'eliminació de residus, especialment quan provenen del sector de la construcció.

Paral·lelament existeix la necessitat de renovar el patrimoni arquitectònic italià, (especialment aquell construït després de la guerra), degut no solament al mal estat de conservació i obsolescència dels components del sistema de construcció emprat, sinó també a donar resposta a les canviants necessitats respecte al moment de la seva construcció.

La investigació identifica les modalitats d'execució quant a la regeneració de les construccions a través de la transformació dels residus en recursos mediambientals o sostenibles. La dimensió local combinada amb la reducció dels residus són garants de la sostenibilitat del procés de regeneració, que comença des dels seus inicis fins a arribar a l'edifici.

L'estudi de les normes i de les bones pràctiques en el camp de la construcció, ha fet possible determinar modalitats d'actuació per a la reutilització de components.

A més, s'han analitzat els mètodes, eines i tècniques per a la demolició garantint la uniformitat dels materials i la integritat dels elements. L'anàlisi dels casos de demolició selectiva ha identificat les possibles maneres d'organització i gestió dels passos operatius encaminats a aconseguir el benefici ambiental. Aquests estan condicionats per la seva gestió a nivell local, la qual cosa fa que, mentre s'efectua la regeneració urbana, es desenvolupe progressivament la cadena de subministrament local sostenible.

Amb l'objectiu de promoure l'explotació de les prestacions residuals dels materials resultants de la demolició selectiva, en el cas de la fusta i l'acer van ser elaborats processos metodològics-operatius per a l'optimització de la seva reutilització.

Pel que concerneix als elements de fusta, les línies metodològiques-operatives tenen en compte la degradació, els tractaments potencials de tipus curatiu i preventiu, la durabilitat respecte a l'espècie en qüestió i a les condicions climàtiques en les quals aquest material es col·loca en la construcció, així com els requisits mínims per a la seva reutilització estructural. En aquest últim cas, les proves de laboratori realitzades han demostrat la inadequació de la classificació visual en la definició de les propietats mecàniques de l'element sota recerca, quan els elements ja han estat utilitzats o provenen de la recuperació. La classificació visual, encara que sempre segura, no proporciona resultats coincidents amb les propietats reals de l'element, causant sovint una subestimació de les propietats mecàniques. El procés proposat té en compte la informació resultant del primer cicle de vida per aprofitar el veritable rendiment de l'element i no el suposat, assegurant la sostenibilitat ambiental del procés de reutilització. En funció de les característiques de l'element i dels tractaments aplicables, s'han definit els nivells específics de reutilització, que permeten al tècnic avaluar les possibles maneres de re-uso, a partir d'un llindar màxim d'explotació del potencial de l'element fins a un llindar mínim, que coincideix amb el dipòsit en abocadors.

Quant als elements d'acer, s'han posat en correlació les normes internacionals vigents i s'ha definit un procés metodològic-operatiu específic per a la seva reutilització. També en aquest cas, l'optimització de reutilització implica l'anàlisi de la informació derivada dels cicles de vida anteriors, l'anàlisi del nivell de la corrosió i de la degradació del tractament de protecció, la identificació dels tractaments que poden ser realitzats i de les prestacions assolibles respecte a la corrosivitat ambiental i una estimació precisa de la durabilitat presumpta, amb la finalitat de programar l'execució del manteniment.

Les teories desenvolupades han estat experimentades al territori de L'Aquila (Itàlia), severament danyat pel terratrèmol ocorregut el dia 6 d'abril de 2009. La reconstrucció és, de fet, una oportunitat per a la regeneració i el desenvolupament de tot el territori, però en l'actualitat té molts problemes d'ordre logístic, ambiental i econòmic. De fet, la necessitat d'intervenció urgent creada pel terratrèmol i la forma d'actuar a gran escala han produït solucions funcionals exclusivament per al moment contingent i no pensades a la llum dels futurs desenvolupaments de la zona. La recuperació de la viabilitat i la preservació dels edificis han necessitat operacions de consolidació dels edificis. Quan comencin les operacions de reconstrucció de l'edifici, aquests sistemes han de ser desmantellats. En l'actualitat no han estat programats escenaris que contemplen la viavilitat de la fi del cicle de vida i els materials que composen els sistemes de seguretat, per tant, van a confluir en l'emmagatzematge o l'abocador temporal. Donada l'enorme quantitat de residus (principalment components d'acer i fusta) resulta un dany molt important tant a nivell econòmic, com ambiental i logístic.

El projecte de recerca defineix línies metodològic-operatives per a la reutilització/recuperació dels materials que composen els sistemes de seguretat dels edificis i identifica maneres d'aconseguir l'optimització i la sostenibilitat del procés de reconstrucció i desenvolupament de cadenes locals de matèries primeres secundàries, que promoguin noves economies.

En concret, l'anàlisi preliminar va consistir en la recerca bibliogràfica, de la normativa i en la realització de diverses inspeccions al territori del terratrèmol, dirigit a identificar la modalitats de consolidació dels edificis, els sistemes constructius instal·lats i els components que els constitueixen. Comparant les dades, les normes i els mètodes d'optimització de la durabilitat de l'acer i de la fusta com es detalla anteriorment, s'ha definit un procés de reutilització específic per al territori de L'Aquila, desenvolupant dues línies de recerca:

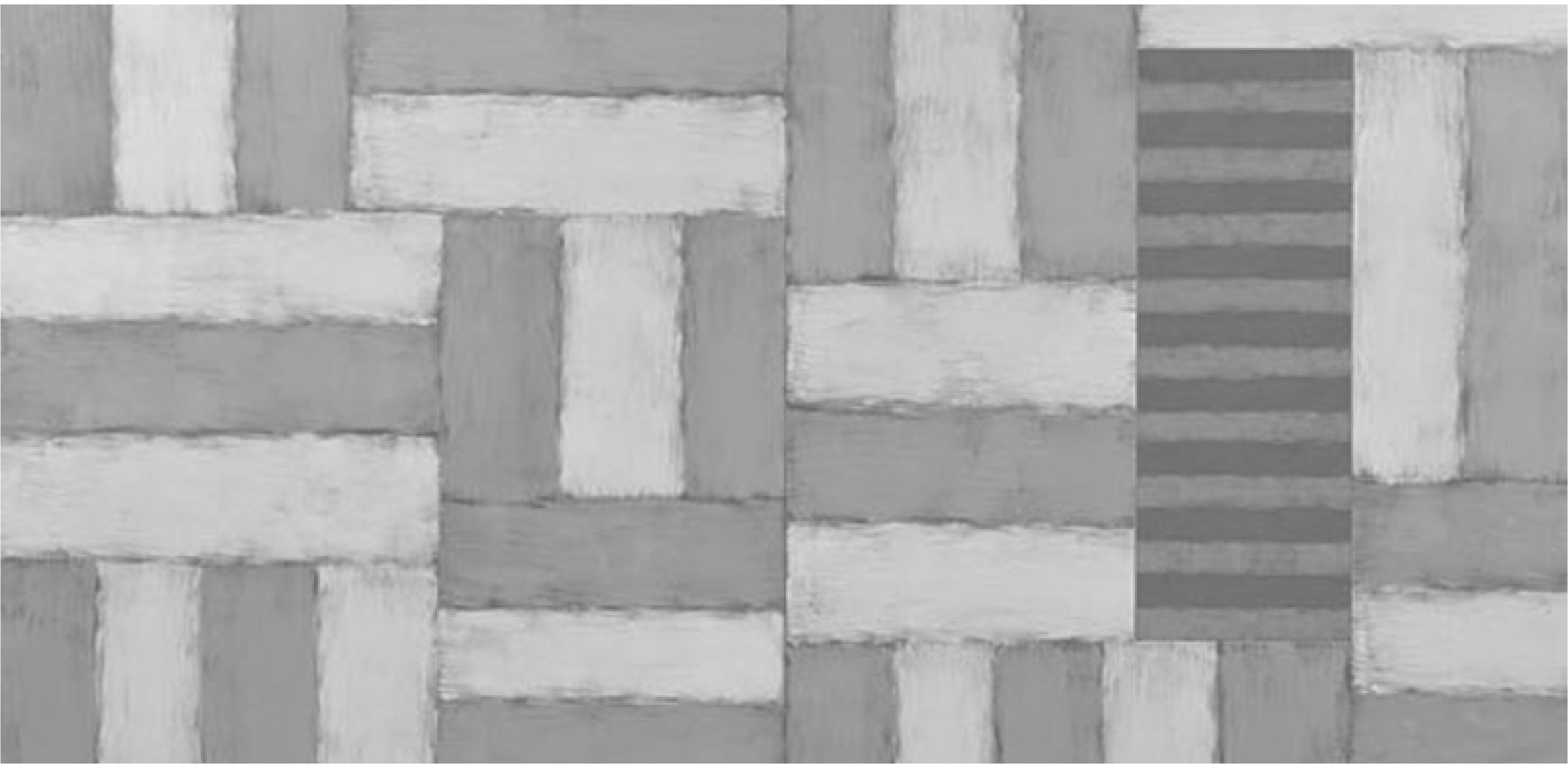
- reutilització endogena: els materials provinents del desmantellament dels sistemes de seguretat que són immediatament reutilitzats dins de l'obra per a l'edificació de construccions temporals o serveis, com a oficines, vestuaris, banys, etc. (reutilització endogena temporal) o s'insereixen en el projecte de reconstrucció amb funció d'ajust/millora de les estructures, de les instal·lacions o dels aspectes o la redefinició de l'espai intern (reutilització endogena;
- reutilització exògena: els materials que deriven del desmantellament dels sistemes de seguretat es reutilitzen en les obres de reconstrucció veïnes (en un radi de 100 km), o per a la construcció d'estructures temporals que alberguen les funcions relacionades amb la comunitat (escoles, oficines, residències , etc.).

Ambdues línies de recerca han estat recolzades per experiments de disseny, en relació en particular amb:

- l'estudi dels mètodes de demolició selectiva dels sistemes de consolidació al Museo Civico de Santa Maria dei Raccomandati, l'estudi de les prestacions residuals i del potencial de reutilització dels materials/components que deriven d'ella i la definició d'un espai comú de l'obra on els serveis (oficines, banys, vestuaris, etc.), siguin construïts amb materials procedents de demolicions selectives properes a la veïna plaça de Santa Maria Paganica per a l'ús programat i simultani de les empreses que operen en la reconstrucció;
- la definició del processament dels passos necessaris per a la renovació d'un edifici pertanyent al patrimoni post-guerra, considerant la realització treballant en cada planta singularment i l'hospitalització dels usuaris en estructures temporals amb elevada eficiència energètica, els components de la qual es deriven del desmantellament dels sistemes de la seguretat.

Finalment, a través de la utilització de la llista de preus de la Regione Abruzzo i l'ús de les dades obtingudes prèviament, ha estat elaborat un full de càlcul per avaluar el benefici ambiental i econòmic resultant de la reutilització per a les empreses i per a les administracions públiques.

La investigació ha permès desenvolupar mètodes de regeneració de la construcció sostenible, que poden ser aplicats també a la reconstrucció en curs a la zona de L'Aquila, per promoure els recursos locals i al mateix temps per resoldre els problemes logístics, econòmics i ambientals relacionats amb aquest procés, transformant la falta d'escenaris de planificació del final del cicle de vida dels materials resultants del desmantellament dels sistemes de seguretat en una important oportunitat per a la innovació.



PHASE 1_ Limits to the field of research.

The first phase of research is to define the field, i.e. the problematic scope in general terms and specific application. Starting from the international debate on the environmental crisis, there are critical issues relating to the exhaustibility of resources, which can be summarized in the categories of air, climate protection, water, soil, and food. Housing regeneration, highlighted as a necessity of modern architecture, becomes a tool for the promotion of local resources. The study of territory and of present and potential local supply chains allow us to identify specific strategies that produce the development of new economies. In particular, the awareness of the potential of the waste, with a view to repackage it and exploit residual performance, encourages the development of a market for secondary raw materials and reduces the environmental impacts resulting from landfilling.
There are numerous examples in the international field for reuse or recycling of materials, with changes in the use aimed at optimizing performances. There are significant challenges within the building field, where the function of components resulting from other fields (pallets, containers, etc.) is revolutionized or materials resulting from selective demolitions are reconditioned.
The increase in the number of years of use for an element allows the exploitation of embodied energy present.
It also has advantages in terms of reducing land use and the impacts of landfilling.
The territory of L'Aquila is currently dealing with the reconstruction after the earthquake of April 6, 2009. This is a *sui generis situation*, where significant factors are involved in terms of the regeneration of the land, building renovation and construction and the limitation of logistical, environmental and economic costs related to the end-of-life reconstruction waste. One of the most relevant issues currently is the end-of-life of materials constituting the safety systems, after the building recovery, they cease to fulfil their function. This research project investigates the possibilities of reusing materials/components that are derived from the selective demolition of safety systems with the aim of triggering closed cycles of matter in order to stimulate the development of the L'Aquila region through the regeneration of damaged or obsolescent buildings. The operative-methodological process allows us to accelerate the reconstruction operations and to transform criticalities into an incentive for local operators by promoting the development of new economies.

1_ RESEARCH ARTICULATION

1.1 _Framing the scientific problem. Building renewal through the enhancement of local resources.

The international debate on the environmental crisis, known since the 1970's, pushes to revise priorities in light of today's time combined with catastrophic future scenarios. If the current graph line continues to rise unchanged in the five key areas (population, industrialization, pollution, food production, consumption of natural resources), humanity will reach its natural limits. A sudden, uncontrollable decline in the level of population and the industrial system will occur. This dire conclusion, made explicit in "The Limits to Growth" in 1972, is our present course.
While this scenario is cataclysmic, it also requires a renewed commitment among various institutions to plan interventions that encourage changes in people's lifestyles, and sensitize the public on the effects that individual action has not just on the current system, but also the future.
The theory of the bio-economy, developed by Georgescu Roegen, is based on the principle that the material in the economic process degrades irreversibly. Raw materials may be used in the economic cycle with a lower potential than present prior to extraction. It is a logical evolution in the present attempt to protect non-renewable resources in exchange for the benefit and use of renewable resources. The exploitation of renewables is potentially controllable, i.e. in the assumption that the opportunity to use a material is established by the impact that it has on environmental balance.
Environmental sustainability means maintaining the natural capital (Carta di Aalborg, 1994). It follows that the rate of consumption of renewable material resources, water and energy resources, does not exceed the rate of reconstruction respectively ensured by natural systems. It also holds that the rate of consumption of non-renewable resources does not exceed the replacement rate of sustainable renewable resources.
From an environmental perspective, sustainability also means that the rate of emitted pollutants does not exceed the capacity of the atmosphere, water, and soil to absorb and process these substances.[1]
Therefore, to control or prevent this environmental crisis means paying attention to the netting of monetary inflows and outflows, and creating closed loops, where the "waste" of a loop cycle feeds differently within the same macro-system. This is according to a complex pattern found in nature where every action has a balanced reaction. It is possible to safeguard fundamental resources for survival. Air, climate protection, water and food are classified as a function of time, during which we cannot live without.[2] In the categories of climate protection and food, soil protection is also implied.
In fact, mobility, water, sanitation services, clean energy, food, health, soil and densification, urban dimension and the capacity of local government are some of the current topics in international law that emphasize the role of the city in response to the environmental crisis through the pursuit of sustainable development.
Specifically, the construction sector is significant due to the strong impact it has in terms of land use, consumption of natural resources (energy and materials), emissions, and waste production. Therefore, it is necessary to revise the paradigms underlying construction with the aim to introduce a methodology that is concrete in strategies and consequent actions to redefine the relationship between the territory, production system, city and building, in terms of sustainability.
From the perspective of reducing land consumption and limiting environmental pollution, the problem of waste disposal holds great importance, especially from the construction sector. In Europe, the production of waste amounts to about 1.3 billion tons per year. Nearly 39% comes from the construction sector, 32% from manufacturing sector, 15% from municipal waste, 10% from the power and water sector and 4% consists of hazardous waste.[3.]

In connection, Italian architectural heritage, especially post-war, is in a bad state of conservation. The Italian building is, in fact, mostly a legacy prior to 1980. Construction growth has been strongly influenced by population growth that affected Italy between 1950 and 1980. However, since 1980, the upward trend of birth has greatly slowed. The period of construction also provides information on the age and is also indicative of the construction techniques and materials used. Anti-seismic regulations came into force in 1974. Since then, buildings have undergone many changes. The buildings constructed prior to this legislation are about 70% of total assets. About 7 million buildings have exceeded 50 years of life. Only 4.3% of the buildings were built after 2001. Analysing the state of conservation of residential buildings, the situation is alarming. An average of 20.3% of homes are in a mediocre state of conservation, and 2.3% are in a very bad state.

In reference to buildings constructed before 1971, 27% are in mediocre state and 3.4% are in a bad state[4].

The need to restore existing buildings does not stem only from the bad state of conservation and obsolescence of the components in the building system, but also by the need to respond to changing needs at the time of the building construction.

The growing demand for compliance with environmental rules and energy efficiency, the components aimed at increasing automation systems and changes in the family structure and way of living need to be considered.

Housing would then require minimum spaces that are flexible and customizable in the same way.

The combination of such critical issues suggests solutions related to recognition and promotion of local resources.

The search for environmental sustainability in construction starts with the awareness of existing problems and changes taking place globally. In addition, this quest also defines common objectives to achieve these answers through strategies implemented locally. To think globally and act locally requires an integrated and consistent "change of scale" that makes every action responsible for the effects that develop in the systems connected to it and locates its foundation and reason to exist.

The building regeneration, therefore, starts from the knowledge of the problems and resources and creates an opportunity to trigger a cascade of noble processes aimed at increasing the quality of life. The transformation of waste into resources at zero distance through appropriate reconditioning and re-use as a component in the redevelopment building allows us to trigger regeneration processes to the entire territory in the following ways:

- we can reduce the impact of waste disposal, both in terms of energy and soil consumption;
- we can enhance the performance of residual materials, promoting the local supply chain of MPS (secondary raw materials), the birth of new closed cycles of matter and their integration with the existing supply chains;
- we can capitalize on the existing building by limiting land use and energy consumption;
- we can trigger new industrial economies by promoting technological innovation.

Solutions aimed to transform critical points into strengths are the key to regeneration. They start from specific interventions and have global repercussions.

1.2 _ Limitation of the research field. The reconstruction of L'Aquila through the reuse of safety system components to secure existing buildings.

The reconstruction of the city of L'Aquila, severely damaged by the earthquake on the 6th of April, 2009, is an opportunity for regeneration and development of the whole territory through localized operations. Inspection checks on the state of the property have provided alarming outcomes. Only 45.7% of the buildings in outcome A had a successful coordinating inspection (n. 9668 buildings viable). While 17.3% of the buildings present in outcome B: n. 3661 buildings are temporarily uninhabitable but useable with emergency measures. The 2.4% presents outcome C (n. 514 partially unusable buildings); the 0.1% presents outcome D (n.20 buildings temporarily unusable for in-depth review), and 34.5% presents outcome E/F (n. 7314 buildings are not useable).[5]

This data emphasizes the need for numerous building renewals due to earthquake damage and additional energy efficient measures for a share of usable buildings.

It is necessary, however, to move away from the logic of rebuilding "as it was, where it was", towards measures to restore to the city its identity as an expression of its nature, which enhances the story and also accepts the changes arising from progress. This is the new paradigm of society. Identity and development are intertwined and complete expression of the genius loci: "To respect the genius loci does not simply mean recopying ancient models, but to highlight the identity of place and interpret it in a new way".[6]

The L'Aquila earthquake crater creates numerous logistical, environmental and economical problems in relation to the reconstruction, which constitutes a formidable field of research and testing. In fact, the state of emergency caused by the earthquake created the need to quickly act in a large scale across the entire territory of L'Aquila. This has produced functional solutions exclusively for the existing moment. Due to structural damage, the restoration of road conditions and the preservation of buildings for artistic and historical value are needed. It became necessary to perform the tasks of securing the buildings.

Temporary safety systems were provided and set in place for a small part by firefighters (mainly wood systems) and the remainder from private companies through proposals issued by municipalities. The contractor's agreements did not provide the rent of safety systems, but instead, the purchase.

When reconstruction operations of a building begin, safety systems should be gradually dismantled. The box-shaped casing is no longer needed to perform their function. As a result, these materials come from construction and demolition (C&D) waste.

The Deputy Commissioner Circle for Reconstruction on

April 28, 2011, Prot. 1712/STM determined that the provisional systems to secure existing buildings taken by public entities are owned by municipalities.
They evaluated the properties and quantity from the same company that offered to dismantle and deliver materials to a specific place. For this reason, public authorities have to bear the economic and logistical burden of disassembly, transport, temporary storage and landfill disposal. In addition to this, we must also consider the environmental impact of transport, most especially the disposal of materials that have undergone a life cycle well below the expected durability, which are in most cases high residual performance. The environmental impact of the production of such materials is reduced over a number of years. It must be reduced and the environmental impact of the production of the same amount of material must be added. If they are not being reused, the materials must be produced ex novo (from scratch). Even if it is placed in temporary storage, the lack of use lowers performance levels depending on the class of environmental risk, which renders this operation unsustainable. We must also consider that both temporary storage and deposits transported to landfills require land, which is a non-renewable resource.
This is a unique situation due to the enormous amount of material that ceases in a limited amount of time to perform the function for which it has been put in place.
The ordinance prot. 55444 of the 17 of June, 2014, signed by the head of the Reconstruction and Heritage of Public Assets, aims to define rules for construction managers and companies that are involved in the dismantling of safety systems. The aim is for them to identify and supervise the quantities of materials.
Specifically, it orders the construction managers for interventions in the progress "of repair, recovery, renovation and reconstruction after the earthquake (...) affected by temporary safety works made by public entities" to make a transcript of consistency with information on the type, quantity and size of the amount of each element resulting from the removal of safety systems.
Also, it mandates to companies that deal with the dismantling to weigh the materials categorized by type and confer them to the points of storage indicated by the town council.
This ordinance establishes a virtuous control cycle. Presently, there are no more further documents regulating disassembly and direct end-of-life scenarios of the materials that constitute the safety systems.
The absence of programming implies that the safety systems, although a very high public expenditure, are required. Upon disassembly, they are soon destined to become residual waste materials without a precise location. This forms a huge burden to the community economically, environmentally and logistically.
The identification and regulation of end-of-life scenarios results in a much more noble dismantling of safety systems through reuse, recycling, recovery (including energy) and identifying ways of demolition to increase the recoverable fraction.
This would alleviate logistical, economic and environmental charges.

1.3 _ The purposes and objectives

The problems related to the lack of planning scenarios for end-of-life materials in the dismantling of safety systems transforms into an opportunity for innovation.
The purpose of the research project is to define the methodological-operative lines of reuse and recycling of materials that make up the safety systems, in order to facilitate and speed the process of reconstruction and building regeneration.
It is assumed that the true knowledge of the logistical, economic, and environmental potential of the recovery operation of materials/components and how to develop these potential incentives and voluntary mechanisms will stimulate specific legislative regulations in this regard.
The possibilities of recovery transforms the enormous amount of steel and wood that is currently wasted, into a local and sustainable resource. Waste materials can be enhanced by entering their process of reconditioning/ treatment in the local supply chain, namely enhancing the cyclical nature of the product within the cyclical process of making the reuse/recycling more sustainable with respect to its implementation in a wider dimension. In fact, the sustainability of reuse/recycling and the local supply chain have a common assumption that is cyclic nature. We cannot say "a priori" that the waste has value, but it can become a resource at zero distance in a local dimension, i.e. when their reuse/recycling contributes to the reduction of land use and resources in one specific territory.
To recover the materials from the safety systems would produce economic advantages for both municipalities and companies. Since the municipalities own the materials with a market value, they may derive gains from the sale, obtaining both the relief of the burden of dismantling and the disposal. For companies, they could buy materials at competitive and "going out of business" prices.
In the regeneration building, they will have available materials and components with high levels of performance at a reduced cost.
Also, the environmental benefits arise from the failure of transport to landfill/storage and disposal of the material, from the exploitation of grey energy and the residual performance and development of the recovery process in a local dimension.
The aim of the research project is to identify ways to pursue the optimization and sustainability of the rebuilding process (defined as the period between the occurrence of the earthquake and the restoration of the buildings) and the development of short chains of secondary raw materials that promote new local economies.
The optimization process of reconstruction is achieved through:

- the reduction of the time and costs of supply to a portion of necessary materials in the reconstruction project; the companies can use the materials that are already on the site of reconstruction;
- the reduction of the logistical and economic burdens, currently imposed on municipalities, resulting from the transport and subsequent storage of the materials that make up the safety systems in deposits; only a

portion of those materials will have to be transported to disposal, as their residual performance will be below the threshold that is considered sufficient, as these materials cannot be used; this reduces the number of areas necessary for storage;

- the definition of logistical site areas for common use by multiple enterprises through the establishment of timelines of work is required to correlate the amount of material available from the progressive dismantling of building safety systems with the simultaneous need for temporary construction site works, built with the same materials;
- the definition of a process to recover the buildings without structural damage, which allows the execution of plans and processes and the refuge of users in sustainable, temporary, energy-efficient modules. The components are derived from the removal of the safety systems, which can speed up regeneration building interventions.

The sustainability of the reconstruction process is achieved in the following ways:

- the reduction of the environmental impact caused by end-of-life scenarios other than the recovery in terms of the materials that comprise the safety systems;
- the development of local sources through the reuse of materials at zero distance; the local supply chain will reduce the environmental impact of transport; companies use materials that can be set to zero meters; during the reconstruction process, the materials resulting from the demolition of the safety systems are used; therefore, they already exist in the same site or neighbouring yard;
- the incentive to apply building regeneration interventions aimed at reducing the consumption of land and energy expenditures;
- the sustainable management of the reconstruction process, with programming on how to of recover materials, is designed to facilitate the control of the whole process and to limit arbitrary choice by companies.

The methodological-operative lines can be applied to all cases where there are considerable quantities of unused steel or wood components. The lines also used when the regeneration building interventions are urgent. Not just at the reconstruction site in the seismic crater, but also at all construction sites where safety systems have been used similar to those in L'Aquila, such as in Emilia Romagna. The development of new local economies are achieved through these methods:

- the encouragement of voluntary mechanisms of creation by companies to market secondary raw materials, which places a commercial value on the material derived from selective demolition;
- the entering of the market for the secondary raw materials in a territorial dimension in the short chain, which becomes the input and the output of the life cycles of materials;
- the component performance implementation, through reused elements derived from the short chain, integrates local materials and materials for reuse.

1.4 _ The methodology

The research path has been developed in progression by using data obtained from a phase of analysis as a basis for the next step.
The end of each phase of research was verified and the congruence between the preventive and subsequent connections was found.
The research path had a linear trend, while the verification of congruence showed a cyclical trend.
Specifically, preliminary analysis consisted of bibliographic and standards research in carrying out several inspections in the seismic crater aimed at identifying ways of securing installed systems and components that constitute them. In addition, visits were carried out at selective demolition sites designed to evaluate the logistics, economics and environmental impact of this building deconstruction method.
Compared to resulting data, starting from the information provided by the regulations, it identified methods to optimize the durability of steel and wood in the reuse. The materials in their technological aspects have been studied and include the residual performance, the environmental risk class performance and potential achievable through treatment.
Concerning the elements in wood for structural use, analysis was carried out in an experimental laboratory on elements of reuse.
The congruence was checked between the resistant class defined by the visual classification and actual resistance values.
Thanks to this method, it was possible to create a reuse manual for steel and wood elements that implements the evaluation process currently described in the legislation.
The performance potential's reach allows us to identify the hypothesis for the reuse of the elements within the recovery project, through the realization of possible interventions, in function to the building element on which it operates. This brings back the phases and variants of realization.
Based on the designed experiments and analysis of the components studied at the proposed construction systems with elements of reuse, technology and assessments for thermal comfort and environmental impact.
Through comparison with the temporary prefabricated building systems present on the market, it has been possible to identify the convenience in terms of technology, comfort and environmental impact arising from the use of building systems made from recovered components.
The construction systems characterized by flexibility and reversibility, as compared to the specific characteristics, can be used as a temporary function inside the reconstruction yard or outside of it.
Through the use of the prices present in the Region Abruzzo 2014 Price List and by using the previously obtained data, a spread sheet assessing the economic gain resulting from the reuse for the company and for public administration has been made.
The methodological-operative process identified has been verified through the application in two case studies.

1.5 _ The content

The research project is structured in the following parts: preliminary analysis, the specific analysis of building elements, and the possibilities for reuse.

The preliminary analysis includes:

- the law of end of life scenarios and the design experiments to reuse both of elements from sectors different to the construction field and elements belonging to the construction industry;
- the analysis of methods, techniques and tools of demolition increase the reusable commodity fraction; this ensures their homogeneity and promotes the integrity of the elements; the samples were analysed elements of selective demolition carried out in the international field; when possible, the economic and environmental convenience were identified.

The specific analysis concern:

- the identification of the costs paid by the public administration for the temporary systems of safety; the study of the mechanism that they oppose, and the analysis of the operation and components of each system, with dimensional and performance indications;
- the identification and analysis of exemplary projects within the international field of building restoration; temporary projects that use materials and components in an innovative way, similar to those used for the safety in the city of L'Aquila, are also noted.

The analysis of the building elements concern:

- the optimization of the reuse of wood elements, through the definition of durability and residual performances, the identification of curative and preventive treatments, the evaluation of the potential structural reuse, the identification of constructive and preventive methods against degradation and the definition of a methodological-operative process for reuse;
- the optimization of the reuse of steel elements, through the identification of corrosion level and residual performance, the identification of preparedness and prevention treatments, the definition of dimensional tolerance, the identification of corrosion prevention construction methods and the definition of a methodological and operational process of reuse.

The possibilities of reuse are divided into:

- endogenous reuse: the materials that are derived from the dismantling of safety systems are immediately reused within the site for the construction of temporary buildings; endogenous temporary use is for yard services such as offices, changing rooms, refectories, toilets, etc.; endogenous permanent use includes the reconstruction project with matching function given to structural or technological adjustment and improvement of installations or the redefinition of the internal space;
- exogenous reuse: the materials that are derived from dismantling the safety systems are reused in neighbouring reconstruction yards within a radius of 100 km; the construction of temporary structures is designed to accommodate the functions related to the community (school, offices, residence, etc.).

1.6 _ The impact on the territory of L'Aquila

The application of the methodological-operative lines identified in the research project creates numerous positive effects in the seismic crater area. In particular:

- it reduces the economic, logistic and environmental issues related to disassembly, transport, storage and end-of-life scenarios for safety systems paid by municipalities; by planning its end of life, the waste becomes a resource for new business, modelled on a similar reference to the reuse of resources in a zero waste system, as opposed to the traditional landfill;
- it enhances the invested economic capital invested by the public; the enormous costs incurred by the Public Administration for the safety of unsafe buildings are even more apparent in reference to the short time of use for the security systems and their required frequent maintenance;
- it speeds up the reconstruction operations by optimizing the logistics of the process through the planning of assistance and the organization of the construction site with areas for common use by multiple companies;
- it ensures a process of sustainable reconstruction; the programming of sustainable reuse of materials from the deconstruction of the safety systems finds a meeting point with the needs of recovery and regeneration building, which reduces environmental burdens;
- it implements the local supply chain and specialization of workers in the technological-building industry; this also promotes the development of new economies.

NOTES

1. *Costanza R. "Ecological Economics." Columbia University Press, 1991*
2. *Friedman Y., "L'architettura di sopravvivenza", Bollati Boringhieri, 2003*
3. *APAT 2006*
4. *Processing and estimates CRESME on Istat data*
5. *The data are taken from the site http://www.comune.laquila.it/pagina79_esiti-delle-verifiche-di-agibilita.html updated on 07/07/2012. According to the "Ordinance 3753/2009: Earthquake events in the province of L'Aquila, 6 April 2009. DICOMAC Function 1 -Technical and Scientific. Clarification on the results of inspections carried out on properties under seismic evaluation." definition of outcomes of coordinating inspection are:*

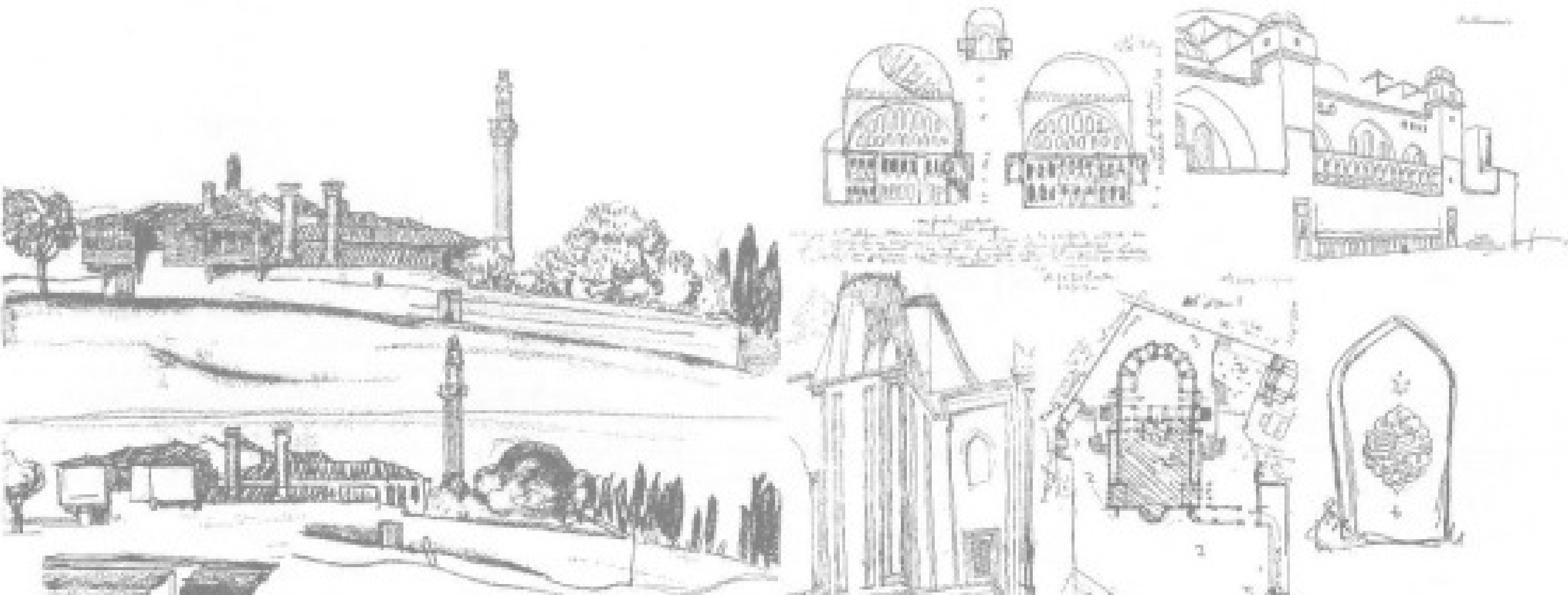
   A- Usable building - The building can be used in all its parts without endangering the lives of residents, even without making some emergency measures. This does not imply that the building was not damaged, but only that the repair is not a necessary element for the maintenance period throughout the building. In the case of a usable building, housing units are not uninhabitable, and families and persons do not have to be evacuated. Obviously, the particular conditions of stress caused by a sequence of shocks can lead citizens to independently make the decision to not use the building.

   B- Temporarily unusable building (all or part), but accessible with emergency measures - The building, in the state in which it is located, it is at least partially unusable, but it is sufficient to perform some emergency measures for reuse in all its parts, without danger to residents. In this case, the inspector offers the measures deemed necessary to continue using the building and notifies the municipality, which will check that the measures recommended were actually carried out, including the receipt of a professional report, and provide for the delisting of inaccessibility.

   C- Partially unusable building - The status of limited portions of the building can be judged to entail high risk to their occupants and point to a judgement of inaccessibility. In case it may be considered that possible further damage in the area declared unfit for use does not compromise the stability of the remainder of the building, and does not constitute a danger to the safety of residents, then it is possible to issue a judgement of partial inaccessibility. In the case of a partially unusable building, the detector indicates and notes which portions of the building are not considered usable. He brings these to the attention of the municipality.

   D- Temporarily unusable building requiring a deeper review - The building has characteristics that make the judgement of the inspection process by the detector uncertain. It prompts a further, more thorough inspection of the first. Until the time of inspection, the building is considered unfit for use.

   E, F- Unusable building.- For the needs of organization, it is distinct in the case of effective inaccessibility of building for structural risk, non-structural or geotechnical (E) by unfitness for serious external risk, or (F), in the absence of significant damages to the building. In the case of outcome E, the building cannot be used in any of its parts, not even as a result of emergency measures. This not to say that the damages are not repairable, but only that the repair requires action via project activities. Therefore, the outcome of unfitness may be attributed to situations characterized by different levels of intensity and extent of damage. This is even in the absence of damages reported by the structural elements inspection. In the case of outcome F, for example, cases such as a heavily damaged bell tower, with possible partial collapses, loom on the building subject to inspection. Also, cases where the threat comes from rocks that can break away from rocky ridge or from slopes by landslide. In these cases, the inspection process is linked to the safety of the building, or from the side or slope that determine the conditions of risk.
6. *Alessi A "Intervista con Christian Norberg Schulz." http:// www.albertoalessi.com/ 1992*



PHASE 2_ Preliminary cognitive-analytic phase. International reflections about the potential of wastes.

The second phase seeks to identify and analyse the potential for waste according to experiments at the international level. This is understood as a potential opportunity that, until today, was untapped. The definition of scrap or waste is generally characterized as an object that is considered to be unusable, since it does not satisfy the minimum performance requirements. The reuse allows us to escape this logic and identify reconditioning treatments that guarantee compliance to specific requirements or change the function of the element ranging (in order of decreasing) performance levels. Historically, the reuse occurred under two different and opposing forces: a push from the bottom dictated by the lack of economic resources, which persist today as testimony to the slums, and a push from the top dictated by the desire to characterise the architecture's symbolic value to the architecture of the past.

Currently, the international legislation identifies its objectives as saving resources, and formalising as virtuous choice the attention to materials that have always characterised the *modus operandi* of people before globalisation.

A hierarchy is introduced in waste management that identifies from the least to the greatest impact: prevention, preparation for re-use, recycling, other type of recovery (e.g., energy recovery) and disposal. This tendency is also reflected in international design experiments that concern building organisms whose components are made of pallets, tires, bottles, cans, containers, railway sleepers and waste from neighbouring industries.

The variation of the concept of waste generates a different focus at the final phase of the life cycle of an object. In the construction field, the necessary condition for the reuse/recycling of materials is the programming and management of demolition phases to ensure the integrity of the materials and the uniformity of the product fraction. The selective deconstruction of the building does not require the use of specific and predetermined demolition tools and methods, but it implies procedural phases. Through the analysis of cases of selective demolition in an international area, and, in particular, the analysis of an experimental demolition made in the Valencian community, we identified the relationships among the phases, the methods and the timing of the demolition, the site organisation, the storage, and the end- of-life scenarios. We then numerically quantified the environmental and economic advantages.

2_ ELEMENTS AND PARAMETERS FOR THE ENHANCEMENT OF COMPONENTS AT END OF LIFE

2.1_ The value of the wastes

What underlies all environmental considerations is finding the problems inherent in the consumption of resources that is expressed in the broad categories of energy, water, materials, and soil (Agenda 21 on Sustainable Construction-CIB). In particular:

- energy: introducing energy-saving measures, such as using cooling and passive cooling technology, the optimization of natural lighting, the use of renewable energy sources and the reduction of transport in favour of the local production chain;
- water: to reduce the consumption of water through the reuse of rain water and grey water, use sanitary low water consumption and drought-resistant plants.
- materials: to use recyclable materials and reduce the extraction of raw materials;
- soil: to regenerate the existing assets and prevent urban decay, ensuring the flexibility and adaptability of buildings.

Each category has specific sub-issues, the repercussions of which are found on the environmental balance of the territory of the building. While pursuing common objectives, strategies for change must be implemented with different modalities.

The protection of material resources (and of other resources to a lesser extent) leads to the enhancement of the performance of residual elements that have already undergone other material lifecycles through reuse/recycling. In fact, the limitation of production and disposal through the exploitation of grey material with recovery operations contributes to the achievement of the balance between inflows and outflows in the environmental system.

In the Conference of the United Nations RIO+20 in 2012, there are issues discussed concerning the green economy, i.e. an economy capable of producing a better quality and more equitably extended state of well-being that improves the quality of the environment and safeguards the natural capital[1].

It should be able to ensure well-being and employment of the entire working-age world population, in spite of the natural and environmental resources becoming increasingly scarce and affected by pollution.

Among the strategic priorities identified for the development of a green economy is the recycling of waste. Consumption of water, soil, material resources and increased emissions are, in fact, the problems associated both with the production of a material and with its landfilling.

The value of waste was reiterated with different modalities and systems throughout history. The concept of reuse was always part of the mindset of man, sometimes operated for lack of new resources, sometimes with symbolic purpose and sometimes the spontaneous result of human activity. Just think of the reuse of the votive materials in the Greek temples, the accumulation of million of shards of amphorae from the river port on the Tiber that generated the Mount Testaccio in Rome, a high hill of 45 metres, or the reuse of coating in bronze and gold removed and transported from the Pantheon to Constantinople by Constantine II in the seventh century.

The reuse is tied to a limited number of operations. This has always allowed them to be used in spontaneous and programmed form, for similar or different uses to those of initial intention.

The Readymade of M. Duchamp, in the early twentieth century, draws the objects used everyday (hangers, rim of a bicycle, urinal, etc.) and turns them into works of art. The reuse consists exclusively in the change of function, in the reversal of the idea that every object underlies. This Dadaist sense of reuse inspires the transformation of an

object into another.
In the reuse, the residual performances of the material/component and performances potentially achievable must first be analysed. Depending on the level of degradation, the material/component can be reused in a similar way to the first cycle of life or according to a method that requires less performance. The reuse is characterized by a close link with the boundary conditions, i.e. the possibilities present in one particular time in a particular territory, which must be made to system with the mode of reuse that optimizes performance and potential residual elements.
The concept of recycling is primarily the result of a post-industrial attitude due to concern about the exhaustion of resources and it was born from the need to reuse materials that had undergone profound changes in factory.
Materials that, without undergoing a further process of transformation, could not have a second life. The treatments must make the material/component competitive on the open market, by the achievement of similar performance to those of the elements produced *ex novo* and at the same time at competitive prices. The material/component can be recycled in the end to ensure performance similar to the element of origin or with slightly reduced performance. The convenience of recycling is measured by the relationship between the economic and environmental impact that present interventions of transformation and the impact of a possible production *ex novo.*
Both in cases of reuse and recycling, it is possible to detect different levels of convenience. A specific operation may be convenient only from an economic point of view, only from an environmental point of view or under both points of view. In consideration of the fact that the objective of conservation of resources arises from environmental concerns, when the operation is convenient only from an economic point of view, it loses its reasons for being.
Otherwise, when it is convenient only from an environmental point of view (although valid in general terms) there is a difficulty of performance caused by the prevailing economic mechanisms. Thus, reuse and recycling can trigger virtuous mechanisms globally only when the environmental aspects are combined with economic ones.
The sensitisation of communities to the value of the waste goes through the awareness of the environmental risks that loom and the economic incentive for the continuation of ways to act virtuous. The international regulations are moving in this direction.

Fig. 1 _ "Orinatoio fontana" Marcel Duchamp, 1917

2.2 _ The regulations

In the face of highly complex legislation, we traced the process of EU directives and of related national legislation that has revolutionised the approach to the issue of waste management by promoting environmental protection through a proper utilisation of natural resources.
The Framework Directive 75/442/EEC has introduced legislation on waste. In particular, the Annex I to the 75/442/EEC directive introduces the European Waste Catalogue, which contains the codes C.E.R. or numerical sequences of six-digits that identify the refuse.
The codes have been inserted inside the List of Waste, established by a decision of the European Union 2000/532/CE. The six digits are divided into pairs (XX YY ZZ). The first pair (XX) represents the category or the building activity that generates the waste. The second pair (YY) represents the building process activity that generates the waste. The third pair (ZZ) identifies the single waste. An asterisk indicates a possible dangerous waste.
The Directive 2006/12/EC has replaced the previous 75/442/CEE, forcing the member States to prohibit the abandonment, dumping and uncontrolled disposal of waste while promoting prevention, recycling and transformation of waste with the aim of re-use. Cooperation is planned between states, designed to create an integrated and adequate network of disposal plants.
The Directive 2008/98/EC of the European Parliament and of the Council has reviewed the Directive 2006/12/EC *in order to clarify some basic subjects such as the definitions of waste, recovery, and disposal, to strengthen measures to prevent waste, to introduce an approach that takes into account the entire life cycle of products and materials not only at the stage where they become waste and to focus on reducing the environmental systems related to production and waste management, thereby strengthening the economic value of the latter. It should also favour the recovery of waste and the reuse of recovered materials to conserve natural resources.*[2]
In the same legislation are defined:

- waste: any substance and object which the holder discards or intends or is required to discard;
- hazardous waste: waste that displays one or more hazardous characteristics;
- waste producer: aanyone whose activities produce waste;
- (original waste producer) or anyone who carries out pre- processing operations, mixing or other opera-

tions resulting in a change in the nature or composition of the waste;

- waste management: the collection, transport, recovery, and disposal of waste, the supervision of such operations, the after- care of disposal sites and actions taken as a dealer or broker;
- reuse: any operation by which products or components that are not waste are used again for the same purposes for which they were conceived;
- recovery: any operation the principal result of which is to allow waste serving a useful purpose by replacing other materials which would otherwise have been reused to fulfil a particular function or prepare them to fulfil that function, in the plant or in the wider economy;
- recycling: any recovery operation by which waste materials are reprocessed into products, materials or substances to be used for their original function or other purposes;
- disposal: a substance or object resulting from a process of production whose primary purpose is not the production of that article;
- by-product: a substance or object, resulting from a production process whose primary purpose is not the production of that item.

In article 6 of the same legislation are defined the conditions for termination of waste. Specifically, it says, *"certain waste ceases to be waste when they are subjected to a recovery operation, including recycling, and meet specific criteria to be established according to the following conditions:*

a) the substance or the object is commonly used for specific purposes;

b) a market or a demand exists for such substance or object;

c) the substance or the object meets the technical requirements for the specific purposes and respects the legislation and the existing standards applicable to products;

d) the use of the substance or object will not lead to overall adverse environmental or human health impacts."

The construction industry uses about half of the material taken[3] and generates about a third of all wastes[4].

Therefore, the reuse of waste materials by C&D is configured as a key operation in achieving the objectives of environmental sustainability under international rules.

In fact, in reference to waste by C&D, in the above Directive, in article 11, paragraph 2b we read: *"In order to comply with the objectives of this Directive, and move towards a European recycling society with a high level of resource efficiency, Member States shall take the necessary measures designed to achieve by 2020, the preparing for re-use, recycling and other material recovery, including backfilling operations using waste to substitute other materials, of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the list of waste shall be increased to a minimum of 70 % by weight."*

In Italy, the waste sector has been regulated organically for the first time with the law Lg. 366/1941, that with the aim *"of protection of hygiene, economy, and decorum"* has identified services of collection, transport, and disposal of municipal solid waste that have the public interest.

Such legislation has been inadequate in the face of a rising population connected with industrial development.

In execution of European directives (75/442/EEC, 76/403/EEC, 78/319/EEC) the DPR 915/1982 was issued, which has introduced the principle "polluter pays". That is the principle according to which the burden of remedying of the environmental damage must be paid by who is responsible for such damage.

Therefore, the public programming has been introduced for the discipline of the activities of waste disposal, the permissions for entities that deal with the disposal of waste and the waste reduction through the rationalisation of management.

The DPR 915/1982 has not promoted the possibility of waste material reuse and recycling, but is primarily concerned with the handling of the same waste material and is inspired by a prevailing logic of emergency and urgency, not prevention. To deal with emergencies, the DPR 915/1982 has undergone many changes and additions, that often weighed down by the administrative complexity and inconsistent with each other and with the community legislation.

With the aim of overcoming the limitations of this legislation, the Parliament with the delegation laws 52/1996 and 146/1994 has delegated the government to the adjustment of waste legislation. It issued the D.Lgs. 22/1997 (implementation of directives) known as the Ronchi Decree, *"aimed to ensure a high level of environmental protection, liability all persons who are part of the life cycle of products from which originate the waste and promotes the recovery and recycling."*

D.Lgs. 389/1997 subsequently amended the Ronchi Decree. The Ronchi Decree has replaced the disposal management concept as it constitutes an activity of public interest and includes the collection, transport, and recovery, in addition to final disposal.

It introduced the priorities of the recovery by reusing and recycling, compared to landfilling. The waste is then inserted in cyclical logic.

The Ronchi Decree was repealed by art. 264 of D.Lgs.152/2006, "Norme in materia ambientale" (Rules on environmental matters)

The D.Lgs 152/2006 is derived from the enabling law 308/2004, which provided for a review of the entire body of law in Italian environmental theme. It had the purposes of *"promotion of levels of quality of human life to be achieved through the protection and improvement of environmental conditions and the prudent and rational utilization of natural resources."* It has introduced:

- procedures for strategic environmental assessment (VAS), environmental impact assessment (VIA) and integrated environmental authorization (IPPC);
- rules on soil conservation, combating desertification, water protection, pollution and water management;
- rules on waste management and remediation of contaminated sites;

- rules of air and reduction of atmosphere emissions;
- rules on compensation claims against the environmental damages.

The issue of waste is placed inside the environmental legislation, confirming the close correlation and interdependence of waste management with the protection of natural resources.

Waste management should be carried out *"in accordance with the principles of precaution, prevention, sustainability, proportionality, accountability, and cooperation of everyone involved in the production, distribution, in the use and consumption of goods giving rise to the waste, as well as the principle the polluter pays"* (art.178).

In Italy, the transposition of the Directive 2008/98/CE is made through the D.Lgs. 3 December 2010 n.205, which amended the D.Lgs. 3 April 2006, n.152, leaving unchanged the definition of waste, but redefining the hierarchy of waste management in:

1. prevention,
2. preparation for reuse,
3. recycling,
4. other types of recovery (such as recovery of energy),
5. disposal.

In annex D of the D.Lgs 205/2010, it proposes the waste classification according to the codes CER. Code 17 identifies waste from construction and demolition (C&D).

For that which concerns waste from C&D in Abruzzo are of particular relevance the OPCM n.3923 del 18.02.2011 "Ulteriori interventi urgenti a fronteggiare gli eventi sismici verificatisi nella Regione Abruzzo il giorno 6 aprile 2009. Norme in materia di smaltimento delle macerie." (Further urgent measures to address the seismic events that occurred in the Abruzzo region on 6 April 2009. Rules on disposal of rubble.) and OPCM n.4014 del 23.03.2012 "Ulteriori interventi urgenti a fronteggiare gli eventi sismici verificatisi nella Regione Abruzzo il giorno 6 aprile 2009." (Further urgent measures to address the seismic events that occurred in the Abruzzo region on April 6 2009). These regulations introduce important procedural requirements.

According to the article 1 paragraph 1 of the OPCM n.4014 del 23.03.2012 *"resulting materials from the collapse of public and private buildings, from demolition and abatement activities of unsafe buildings, as well as, by building work, however denominated, carried out on behalf of the Government as a result of the earthquake of 6 April 2009, they are managed by Municipalities understanding with the implementing body of article 2. Public Administration, in commending work, directory to have the appointed persons to conduct selective demolition and/or selective collection to group these markets in similar categories, characterize them and identify them with the corresponding code CER to put them...in sites of temporary storage and selection...or to waste recovery and/or authorized disposal or at public areas..."*

At paragraph 2 of the same article we read: "the materials referred to in paragraph 1 that for technical, economic, or management reasons, are not in the collection phase, grouped by homogeneous categories, characterisable and identifiable with the corresponding code CER, are, considered municipal waste with code CER 20.03.99, limited to the stages of collection and transport to temporary storage or storage sites."

Also in paragraph 3 of the same article we read: *"the Municipalities to optimize the collection of materials...are allowed to locate and organize, with positioning of containers divided into homogeneous material, for the duration of the state of emergency, public areas for their contribution by the persons in charge of the work."*

There is an incentive by the regulatory practices to increase the possibility of reuse of materials, thereby reducing the level of waste production.

It should be noted that while the concept of matters, substance, and secondary product provides in its interior the existence of a refusal, i.e. an object or a substance of which the holder is undone. Otherwise, the concept of a product does not include within the concept of waste, as it implies a program that replaces, in the context of further industrial processing, a resulting product from previous processing.

With the aim to establish the definition of reuse rather than recycling, it is necessary to assume a waste; however, if in this context careful planning was present, the object or substance in question would not be classified as waste, since it would not define a condition in which the holder discards the object, but would incur a condition of exchange or a transition from one cycle to another. The waste would be defined in a longer time span and would represent the end-of-life phase of an object or a substance that, after having undergone many cycles of life and having performed different functions, does not present more chances but only to landfilling.

The substance or the object would be thereby included conceptually in a cyclical process that *in nuce* assumes the possible transformations and defines one end of life: the landfill. This is a utopian perspective that brings with it a question about the reasons that induce a holder to dispose of an object or a substance.

It becomes reality only if there is present an environmental and/or economic convenience. Not only for the community, but also for the holder in retaining the object or the substance in question and in establishing an exchange that brings an advantage rather than a deprivation, in lieu of solely that a virtuous cycle process that feeds on itself can be generated.

Many companies operate on this principle (such as IMEX - Industrial Materials Exchange in Washington). An online management platform picks up materials from whomever wants to undo them and sells them to whomever is able to reuse or recycle them. This frees the holder from the economic burden of disposing and favours the buyer with competitive prices.

Similarly, the collection and compaction of packaging and wrappings, present in many European cities, for every object collected grants incentives (for example, glass, plastic bottles, or tin) for recycling.

Thus, the concept of "polluter pays" is integrated with "who does not pollute, earns".

Fig. 2 _ “The Big Crunch” Raumlabor, 2011

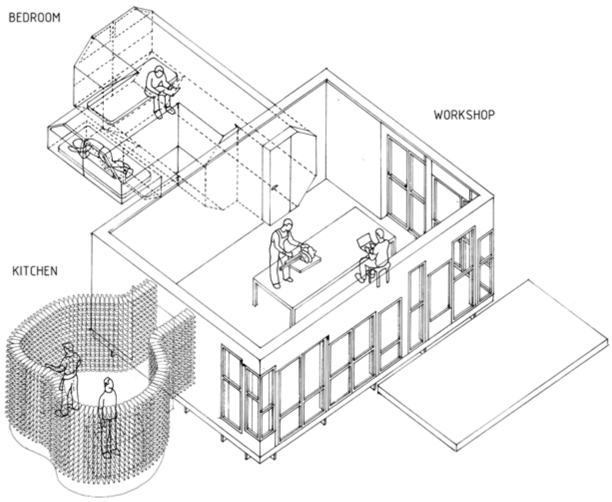


Fig. 3 _ “Officina Roma” Raumlabor, 2011

Fig. 4 _ “Officina Roma” Raumlabor, 2011

2.3 _ Best practices in construction

In construction, from the turn of the millennium, we saw the development of project experimentations that have a large part of recovered materials/components that are used or recycled elements. Such experimentations sometimes take even a function of environmental pollution complaint.

This is the case for the project “The Big Crunch,” made in 2001 by Raumlabor in Darmstadt. In cosmology, the Big Crunch is one of the possible scenarios for the end of universe, where space expansion is reversed and the universe collapses into a black hole. “The Big Crunch” is a project that aims to raise awareness of the community to the value of reusing materials that are typically thrown away. The structure has two openings that allow access to an interior room, a place of meeting and discussion. The architectural work seems to be the result of the passage of a tornado and it appears to roll toward the adjacent theatre. A metal frame in multidirectional scaffolding, covered by a wood pattern, constitutes the central part of the architectural work. A range of waste materials (windows, doors, refrigerators, furniture, chairs and tables, etc.) that they have recovered from an adjacent landfill are hung to it and are arranged so as to deliberately create an atmosphere of chaos.

Similarly, the project “Officina Roma,” carried out in 2011 by Raumlabor, within the RECYCLE exhibition staged at MAXXI, aims to denounce the modern way of life and raise awareness to the community to waste reduction.

“Officina Roma” is a living module composed of a living room, kitchen, bedroom and a bathroom. It was erected using exclusively waste materials derived from previous exhibition installations from the museum.

A collage of pieces including doors, wardrobe, glass bottles, windows, multi-layer panels, car doors, barrels of oil, form the horizontal and vertical closures. The reuse of waste materials has made it possible to experiment on their performances, since the house had to meet specific safety requirements as it is built in a public place.

To make a material/component suitable for reuse, it is necessary that in its phase of reuse it is not subject to undue wear and that a possible lowering of the traditional performance is in any case compatible with the new function. Sometimes a material/component in its traditional field of use no longer presents the minimum requirements; however, in a different field of use, thus performing a different function to a different request for performance, is still able to meet minimum requirements of its new function. In the construction industry are several ongoing experiments, in which materials that are not equipped with a high economic value are acquired from other fields. These materials are used with the aim of achieving the same performance of traditional materials/components related to the field of construction, but they present a substantially higher cost. The simplicity of components and construction techniques used often favours homemade mechanisms. The reuse is presented as a virtuous operation, not only from an environmental point of view, but also economic.

One of the first experiments is the project “Raylway Sleep-

er House," made in 1980 by Takasuga in Miyakejima, an island in the Pacific Ocean. It was designed by the students of New Left and by members of the "Peace Movement", as a place to study and to retire. Due to financial problems, its future inhabitants utilized homemade mechanisms to build their house. The common areas are on the ground floor (bathrooms, kitchen, living area, etc.) and present areas to the entire height. The rooms and the ancillary rooms are on the upper floor. They used old wooden railroad ties, which have a guaranteed lifetime equal to five years. The interlocking building system resembles construction systems made in traditional Japanese architecture. The roof is covered with tiles and wood. The innovation consists in re-use of railroad ties, especially in the use of a single standardized component for the construction of the whole structure and both of the vertical and horizontal closures. Another example of enhancement of the residual performances of materials from other fields in construction is the project "Corrugated Cardboard Pod," carried out in 2001 by Rural Studio at Newbern in Alabama.
The home has a structure with supporting partitions consisting of "bricks" made with compressed bales of cardboard, taken from local discharges.
In fact, the type of carton used could not have been subjected to recycling due to the presence of wax, such as from sandwich panels where a corrugated cardboard sheet is interposed between two sheets of paperboard. On the contrary, this characteristic has decreased the permeability of the material and the walls of the house. They are guaranteed to casing and also have excellent energy performance. The roof was anchored on wooden elements placed at the summit of vertical closures. For the foundations, bales of cardboard have been used, wrapped in a plastic sheet and covered in cement. The weight of the bales of cardboard varies between 750 and 1250 pounds. The success of the experimentation has prompted farmers and local entrepreneurs to use the material for stables and sheds.
The "Paper House" designed by Ben and Daniel Dratz, created in 2010 in Essen, uses with the function of "brick" compressed bales of recycled paper, coming from supermarkets in the area. To ensure better adhesion they have been glued together. The modularity of the bales has allowed for high flexibility in the architecture. Moreover, the insulating paper has provided benefits, especially in summer conditions, causing a lowering of the internal temperature of 10 degrees compared to the outer.
A unique experiment is the hotel "Dasparkhotel," built by Andreas Strauss in Ottensheim, which reuses sewage pipes as casing for housing space of the rooms. Each tube has a length of 2.27 metres, an internal diameter of 2.02 metres, an outer diameter of 2.5 metres, and weighs 9.5 tons. They can be used from June to September, as they do not have heating systems. The cement provides good thermal and acoustic comfort.
Another example of reusing is "Pallet House," designed by Andreas Schnetzer and Gregor Pils and realized for the first time in 2008. The module has closures made entirety of pallets and has an area of 5 square metres. It can be used as a first emergency home and for other uses (tempo-

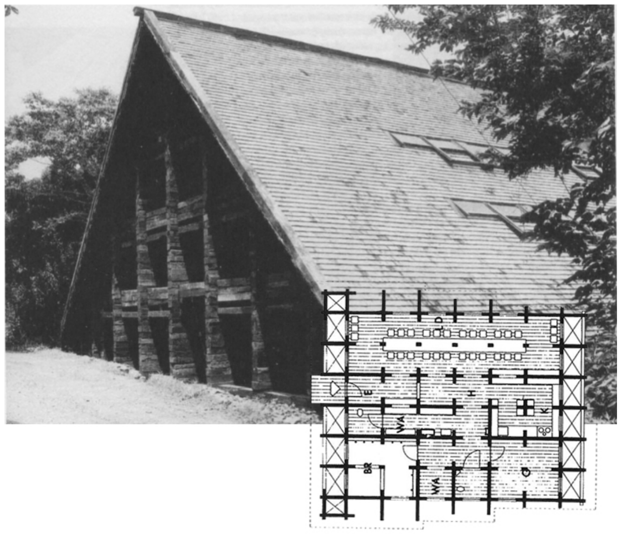


Fig. 5 _ "Raylway Sleeper House" Shin Takasuga, 1980

Fig. 6 _ "Corrugated Cardboard Pod" Rural Studio, 2001

Fig. 7 _ "Paper House" Bem e Daniel Dratz, 2010

Fig. 8 _ "Dasparkhotel" Andreas Strauss, 2004

Fig. 9 _ “Pallet House”, A. Schnetzer e G. Pils, 2008

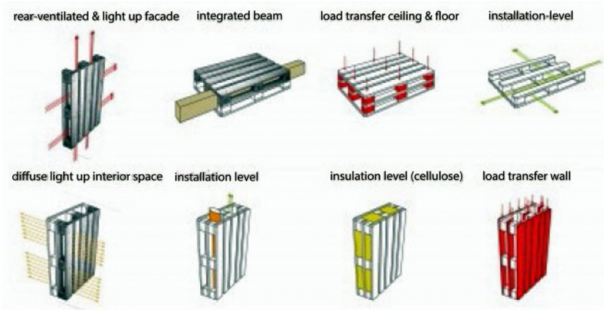


Fig. 10 _ Building system of “Pallet House”

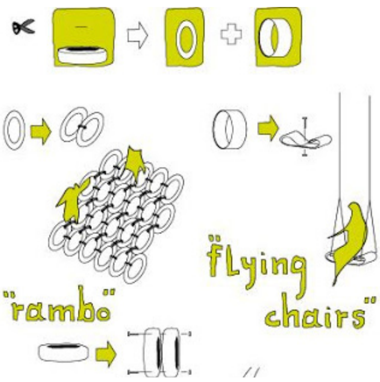


Fig. 11 _ Assembly diagram of project “REU”

Fig. 12 _ “REU” Basurama, 2009

rary installations, first aid etc.) Each pallet has a cost of $5, and the entire module has a cost of $11/sq.m.
Pallets have standard dimensions (120x80x14.5) worldwide. In addition to being easily transportable, they are “universal” components that can be integrated with local resources. The module is extremely flexible both from a functional and dimensional point of view. The construction system provides that, in the cavity of the pallet, intended in the common use for lifting by means of the insertion of forklift blades, pass the support posts, the isolation, and the installations.
Elements of reuse can also be exploited to configure any open space for collective use. The project REU (Recycling Urban Space), of the collective Basurama in 2009 in Lima, combines the reuse of waste materials with the recovery of a degraded urban area. The infrastructure, which should have allowed the transit of trams through the city for several kilometres, although begun in 1968, was never completed. It is elevated from the ground and is 9 metres wide. The project gives life to this abandoned space, turning it into a space for the enjoyments of the community. The used tires and other parts of the machines, symbols of the massive use of cars in the twenty-first century, have been turned into games for the community. The support pylons of the road way are covered with colours that create a playful atmosphere. The games are connected by ropes to the side of the roadway or to columns. The latter remained incomplete, showing the steel reinforcement.
To obtain an actual environmental benefit, it is important to act with the reuse when the material/component has reached its end-of-life phase, i.e. when it no longer meets the requirements.
Consider, for example, the countless cases of containers that are reused in the construction field thanks to their modularity. If the containers that are reused in the construction field through appropriate processes were still able to perform their original function of storage of material for transportation and were subtracted from such use, we should be provided for their new production. On the one hand, there would be an environmental benefit due to the reduction of the environmental impact of the production of the materials needed for traditional building construction. On the other hand, there would still be an environmental impact due to the reconditioning needed to make a container that meets the necessary comfort requirements in buildings and for the new production of the container taken away from its original function.
There are numerous examples of reuse of shipping containers in construction. Among all, it describes for architectonical quality and for consistency in the use of materials. The project “Freitag Flagship Store,” designed by Spillmannechsle and realized in 2006 in Zurich consists of a tower of decommissioned containers. It is located in a suburban industrial area, located between the motorway ramp and the railway viaduct adjacent the factory. The building consists of nine stacked containers, 26 metres high (maximum allowed) and recognizable from the highway, representing a sign of regional scale. The short walls of four containers were replaced with windows (2.50x2.70 metres) that provide a view of the highway.

At the last level, there is an observatory on the city, equipped with binoculars, open to all and accessible through an iron industrial staircase, located outside of the first four levels of the building. It is composed of seventeen rusty containers that arrived in the construction site by rail from Hamburg to Zurich. It has a dry constructive system and the containers were set by elements from the field of maritime expeditions. In front, the Sant'Andrea crosses are visible, which counterbalance the structure and anchor the modules together.
Within, the containers are finished with a colour contrast between the floor in dark wooden boards and white walls.
An extreme case of reuse is, unfortunately, what happens in the slums where the inhabitants use materials that have been dumped in landfill (maps, sheets, clothes, plastic panels etc.), but that retain their grey energy, to build makeshift shelters because of their poverty. Such reuse does not meet the requirements of comfort or healthiness, but surely this may be defined sustainable as there are no present processes or work reconditioning the material as the sourcing is local and it uses materials effectively taken from the landfill, that would not have a second chance of life. It is a sad case of "sustainably inhuman" utilisation.
A positive evolution of the "need for reuse" in the slums is made up of the project experiments that pay attention to the origins of the local supply chain of reused materials, thus combining the environmental sustainability operation of reuse with that resulting from short chain.
The 2010 project "Villa Walpeloo", made in Enshede by 2012 Architeckten, is a house built for a couple of art collectors. The project starts from a detailed study of the construction site and retrieval of materials within 15 kilometres. Thus, they are reused elements that have an original function that are no longer able to meet the requirements, but which have characteristics such that they can be reused with another aim. The materials used externally are 60% derived from reuse and the materials used internally are a staggering 90% derived from reuse. The structure consists of metal sections taken from the deconstruction of a machine of a nearby textile factory.
The wooden facades constitute central elements of 1000 unused bobbins for winding cables. The panes of windows are made thanks to waste from a nearby factory. The polystyrene insulation comes from a nearby factory that produces caravans. For the interior, they have used waste materials such as the structure of broken umbrellas for lamps and advertising board for furniture. The elevator used in the yard was integrated into the house.
In keeping with the spirit that has led to the definition of this project, only highly reversible connections have been used, preferring bolting to welding.
The reuse may also occur in a programmed way, i.e. hypothesising during the production an element's future possibilities once the first cycle of life is finished.
The component is packed with features and performances to create a real possibility of reuse.
An early example of programmed reuse was made by A.F. Heineken, owner of the namesake brewery that, in a 1957 trip to the Netherlands, Heineken realized that the area presented both a shortage of building materials and

Fig. 13 _ "Freitag Flagship Store" Spillmannechsle, 2006

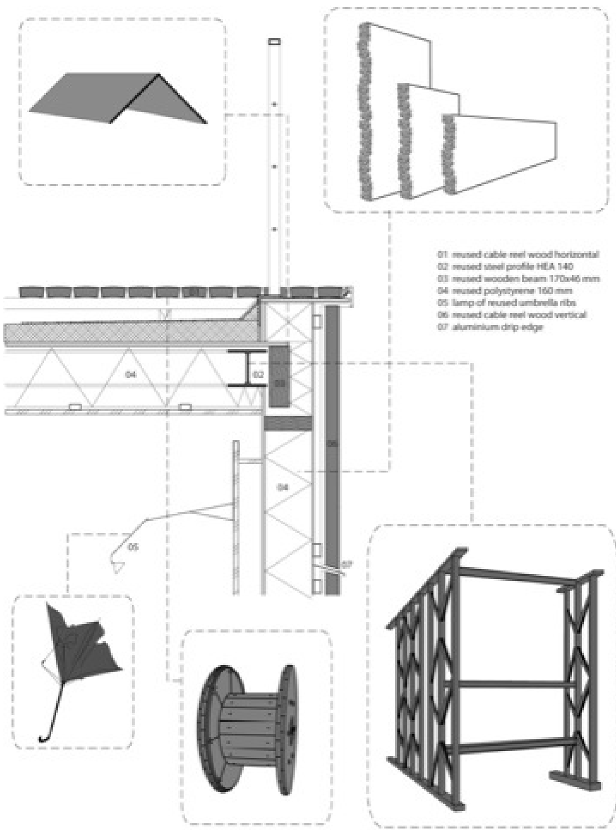


Fig. 14 _Building system of "Villa Welpeloo"

Fig. 15 _ "Villa Welpeloo", 2012Architekten, 2010

Fig. 16 _ Bottle Heineken, J. Habraken, 1957

Fig. 17 _ Realization of prototype with Heineken bottles

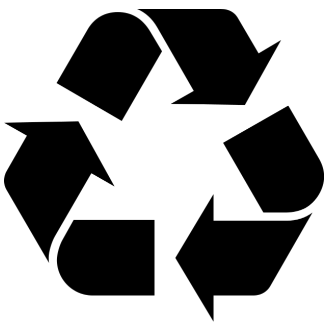


Fig. 18 _ International symbol of recycling

a large amount of bottles abandoned on the beach. On his post, J. Habraken studied a bottle with a rectangular shape with two flat faces, two concave and two convex, so as to be easily stackable. Bottles, once their first cycle of life as beer containers was completed, could be used as a building material. Each bottle was a "brick" and the particular form it guaranteed the possibility of interlocking with other similar elements.
Although such testing was not as successful as hoped, he introduced the concept of programming of the end-of-life in a perspective of sustainability.
Recycling, instead, generally produces a higher environmental impact than reuse, but configures itself equally as a virtuous of end-of-life scenario.
The recycle symbol is formed by three faces arranged in a circular manner. An arrow indicates the act of separation at source i.e. the materials are separated from waste and placed in the recycling, an arrow indicates the treatment of the material through different processes of working and an arrow indicates the reintroduction of the new product into the market.
Recycling is closed when, thanks to the working processes, it gets the same material. Otherwise recycling is open when it gets a different material.
Depending on the type of material and its CER code, they use different cycles of work. These differences in processing are among the main causes of the lack of possibility of recycling components that have different materials made integral by means of connections that are not reversible. It follows that the reversibility of the elements that form the component is one of the prerequisites both to increase the possibility of recycling and to improve the quality of secondary raw material.
Given the current focus on the sustainability of the products, numerous companies experience new products with a higher percentage of recycled material. They also introduced environmental product certifications (ISO 14021, ISO 14024 , ISO 14025) through which it is possible direct consumer choices towards products that are more respectful of the environment and can be either compulsory or voluntary.
In construction, there are numerous tests to verify the compliance of a recycled material/ component to specific requisite and to verify the real performances.
The experimental project "Recyhouse," made in 2001 in Limelette and designed by the Belgian Building Research Institute, aims to demonstrate that it is possible to construct a building almost entirely from recycled materials. In addition to a modest price, the building also offers appropriate technical and aesthetic performances. Throughout the building, with the exclusion of the structural part, there exists a high-level reversibility, allowing the replacement of some materials with others just as they come out in the market. This permits the study of the deterioration of recycled materials over time.
Thus, the correspondence of the actual materials to indicated performance by builders has been verified. The roof of the buildings covered both with roof tiles made of plastic materials or paper/fabric, with each element being derived from either recycled tires or corrugated pa-

per/cardboard impregnated with bitumen, respectively. The windows are obtained from the recycling of polyvinyl. Insulation is in rock- recycled wool. The panels are made from concrete and glasses of crushed computers. Even the downspouts are made of recycled zinc. Inside the building there are about 150 different materials resulting from recycling. Materials containing a substantial portion of material resulting from the recycling of materials that already had suffered a life cycle have been mainly used.
In the same year (2001), another experimental project "Hanil Visitors Center" was made in Danyang and designed by the study BCHO Architects-Byoung Soo Cho to identify the potential of recycled concrete. The latter has been used in various ways, showing the possible applications. In the South part, the concrete, after being crushed, was inserted into metal gabions. The East prospectus was realized in collaboration with a Canadian company specializing in textile formwork, with the aid of tubes and strips of polyethylene, giving the facade a lively look. The facade to the West and North have instead been realized with traditional formwork in wooden boards, inside which is positioned the reinforcing steel and cast with concrete.
The Westborough School made in 2011 in Westcliff on Sea and designed by ACottrell & Vermeulen Architecture with the aim of enhancing paper and cardboard as recycled and recyclable building materials. Before building, the feasibility of the technological system was verified through an experimental prototype form, which resulted in several modifications of technical specifications. In the project, the structural characteristics and mechanical strength of the paperboard to form due to folding sheets were measured. The project required two years of work, one year for research, six months for the prototype and six months for realization on-site. It has a total cost of 177.157 pounds. The cycle of life expected for the building is 20 years, at the end of which, the materials may again be subjected to recycling.

Fig. 19 _ "Recyhouse"
Belgian Building Research Institute, 2001

Fig. 20 _ "Hanil Visitors Center"
BCHO Architects, Byoung Soo Cho, 2001

Fig. 21 _ "Westborough School"
ACottrell & Vermeulen Architecture, 2011

NOTES

1. *Definition of UNEP, United Nations Environment Program.*
2. *Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives*
3. *COM (2011) 571*
4. *Study "Management of CDW in the EU": ec.europa.eu/environmemnt/waste/pdf/2011_CDW_Report.pdf*

3_ ELEMENTS AND PARAMETERS FOR THE ENHANCEMENT OF DEMOLITION OPERATIONS

3.1 _ The C&D waste

The withdrawal of resources higher than their renewal has produced and continues to produce an amount of waste greater than the capacity of absorption for the environmental system.
The waste C&D includes:

- waste from construction and demolition, with code CER 17, excluding soil from contaminated sites;
- waste from code CER 20, different from 17, which may be produced in the activities of C&D, such as packaging;
- special hazardous waste resulting from C&D activities (asbestos, lead, etc.);
- waste from road construction activities.

There is an evident increase in production of the waste from C&D in all European countries, with the sole exception of Germany. The European average is about 3.5 tons/inhabitant, only 28% of waste from C&D is reused/recycled, the remaining part is transported to the landfill[1].
Only seven states apply a tax on inert waste. The Netherlands and Denmark, which have the highest values of fees for waste disposal from C&D, are the states that have the highest level of recycling for this waste. With reference to the demolition waste in the Netherlands and Denmark, the release of "demolition permits" is subject to a control system for the recovery/recycling of the material.
International experiences show that an organized network of plants, regulatory constraints and economic benefits derived from the recovery/recycling of C&D waste, create a behavioural imperative. From an environmental and economic point of view, this is a virtuous operation, both on the part of construction/demolition companies from treatment plants.
IIn Italy there are many factors that limit the recovery/recycling of materials from C&D.
First of all, it should be noted that the prevailing sector is micro- demolition (90%)[2] which originates piecemeal interventions that are difficult to be controlled.
Micro-demolition also has logistical difficulties in preparing areas for storing separate waste, as its groups must be homogeneous.
This type of demolition also lacks an organized network needed to spread throughout the country, which involves treatment plants for industrial production of secondary raw materials. In particular, there is a numerical imbalance between the treatment plants and landfill sites in Northern Italy and those present in the Centre and South, which are far less in number.[3]
In addition, Italy has a significant amount of quarries that supply a low-cost production of aggregates that discourage recycling.

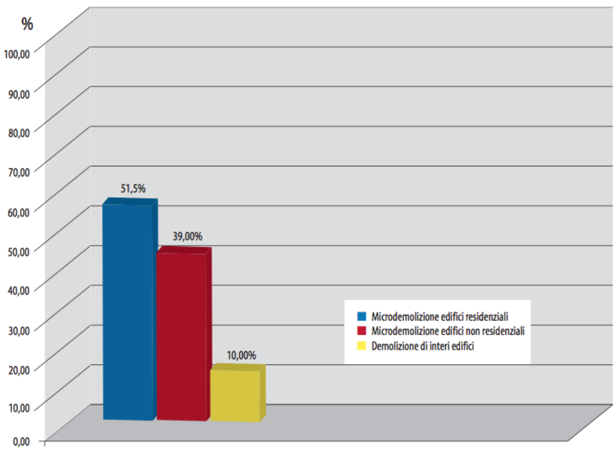


Fig.1 _ Origin of C&D waste in Italy

The C&D activities mainly produce non-hazardous waste, but in significant quantities, and with product fraction variables such as wood, metals, ceramics, bricks, cement, etc. It is a complex nature that requires careful management.
Waste can be reused on site after being treated or it can be transported to plants for recovery/recycling or landfill.
They can be divided into three categories:

- reusable components: integral elements that can be used again as a result of minor reprocessing (cleaning, verification of performances); these components can be used as windows, beams, grates, tiles, etc.;
- recyclable materials: material fractions that have not maintained the original shape and function; they consist mainly from the litoide inert fraction, which undergoes operations of crushing, screening by other organic components, and is subject to incineration;
- waste for disposal: hazardous or polluting materials, or excessively heterogeneous waste that precludes selective operations.

In the demolition, such distribution is closely related to the activities of material separation and storage. The aim is to simplify the construction yard operations and, at the same time, define suitable end-of-life scenarios.
C&D waste are mainly made up of standardized categories. Although found in different percentages, they are conditioned by prevailing materials and by construction techniques.
The categories of waste that are most frequently found in the construction and demolition yards, when they are separating and sorting are as follows: iron and steel CER 17.04.05; mixed metals CER 17.04.07; wood CER 17.02.01; building material CER 17.01.07; materials based on gypsum contaminated with dangerous substances CER 17.08.01; materials based on gypsum (different from CER 17.08.01) CER 17.08.02.; mixed construction and demolition waste (different from those mentioned in CER 17.09.01, CER 17.09.02, CER 17.09.03) CER 17.09.04; bulky waste CER 20.03.07; WEEE waste CER 20.01.23, CER 20.01.35, CER 20.01.36; insulation materials CER 17.06.03, CER 17.06.04; electrical cables CER 17.04.11; accumulator batteries CER 20.01.33., CER 20.01.34; non-recyclable waste not CER 20.03.99; if resulting from mechanical sorting CER 19.12.12.

Categoria di rifiuto	Danimarca	Germania	Italia	U.S.A.
Calcestruzzo non armato			10.0	
	83.8	40.0		77.0
Calcestruzzo armato			20.0	
Laterizio (tegole, mattoni, forati)		47.0	50.0	4.5
Asfalti			5.0	
Scavi			6.0-10.0	
Legno	12.5	7.0		11.0
Carta e cartone	0.2		0.6-4.0	
Plastica	0.4	4.0		0.3
Metallo	2.5		3.0	3.2
Gesso				4.0
Inerte		2.0		
Varie	0.6		1.0-1.4	

Fig. 2 _ Weight composition of the waste (average %)

3.2 _ Methods, tools and techniques of demolition

The demolition is the "operation and also the effect of breaking down and dismantling"[4] a building in whole or partial way.
The partial demolition is an intervention that does not involve the totality of the building and requires the use of small machinery that is easily transportable.
Total demolition involves the entire building. The techniques used depend on the shape of the building (number of floors, cluttered floor plan, construction features, etc.), and from the boundary conditions, such as the distance of surrounding buildings. It is a function that requires a prior knowledge of the building and the careful planning of all phases. This also includes the variability due to the presence of different construction systems that depend on the time, place and building location.
The construction may have suffered structural modifications or levels of adjustment compared to the original design and materials may have degraded (e.g. the oxidation of steel). The demolition is also a phase of extreme importance, since its programming and management affect the possibility of reuse and recycling of the materials and components that constitute the building.
Regardless of the type of demolition, techniques, and instruments used, the first step is the removal of hazardous materials. This ensures safeguards for the environment and operators.
C&D waste can be dangerous[5] for the following reasons:

- they contain a portion of materials considered to be hazardous, such as asbestos, lead, tar, adhesives, etc.
- they can become dangerous after a long period of time in the environment in which they are located (as the surface reaction between materials and the chemical agents due to pollution);
- they are subject to special conditions (such as wood treated with pesticides and the combustion emits toxic gases);
- are contaminated by other hazardous materials, such as lead paint.

The dangerousness of waste from C&D is defined by the leaching test. It consists of a gradual release of contaminants carried out by placing into contact for a set time a solid (the waste, the contaminated soil or the artefact in general) with a leaching (usually an aqueous solution), and evaluating the concentration of pollution that the waste is able to release through percolation.
Depending on the concentration of certain substances considered dangerous, the waste can be transported to a landfill for hazardous waste, for non-hazardous or inert waste or transformed into a secondary raw material.
When it is not possible to remove the hazardous materials prior to demolition hazardous because of their placement, the construction crew will have to schedule a specific phase for techniques and devices that ensure the safety of the workers.
The most common hazardous materials used in construction are listed below .[6]

Product	Prevalent use	Treatment / Disposal
Asbestos	Roofing, pipes, tanks, plasters, water-proofing, exhaust pipes	Controlled conditions of removal for special disposal
Lead	Pipes, paints, slabs acoustic insulation	Removal and separation for special disposal
Hydrocarbon solvents	Cement (additives)	Return to supplier / Recycling / Removal for special disposal
Bituminous solvents	Waterproofing, adhesives, pitching, flooring	Return to supplier / Pre-disposal treatment/ Removal for special disposal
Isocyanates solvents	Adhesives, sealants, resins	Return to supplier / Pre-disposal treatment/ Removal for special disposal
Treated wood	Boards, beams, elements	Reuse/Ricycling
Drywall	Partitions, ceilings	Return to supplier / Recycling / Removal for special disposal

The traditional demolition involves the deconstruction of the building without attention to the various product fractions nor the integrity of the components, with the exception to hazardous materials.
It is fast type of demolition with tools and techniques that produce mixed waste.
The waste cannot be recycled due to its excessive heterogeneity and is transported to landfill.
The heterogeneous portion that presents the prevalence of a material fraction is transported to the selection facilities. By means of different techniques and variables, depending on the type of waste present, the material fractions that can be recycled are separated and packaged. After this, they are transported to the treatment plants.
Depending on the quality of the material, it is recycled to produce elements with similar or lower performance requirements.
Selective demolition; however, is a sustainable mode of building deconstruction that achieves homogeneous groups and preserves the integrity of materials/components that convert waste into resources, which make them reusable and/or recyclable.
It increases the share of reusable components and recyclable materials, and significantly decreases the portion of waste for disposal.
It is a noble practice from an environmental perspective. Restrictions imposed on the landfill and land use enhance the residual performance of materials and components, which increases the potential for reuse.This also increases the quality of secondary raw materials. It decreases the possibility of pollution by recovery or recycling of poor quality, such as the cases of soil contamination due to uncontrolled fills generated by mobile crushers.
Both traditional and selective demolitions can be performed using different methods and techniques.
They are conditioned by machinery, facilities, and tools used to carry out the demolition.
The choice of instruments depending on the boundary conditions, uses simple or a combination of tools, and the change in the organization of the demolition (joint or specific phases) produces a variation in the percentage of recoverable materials and components.

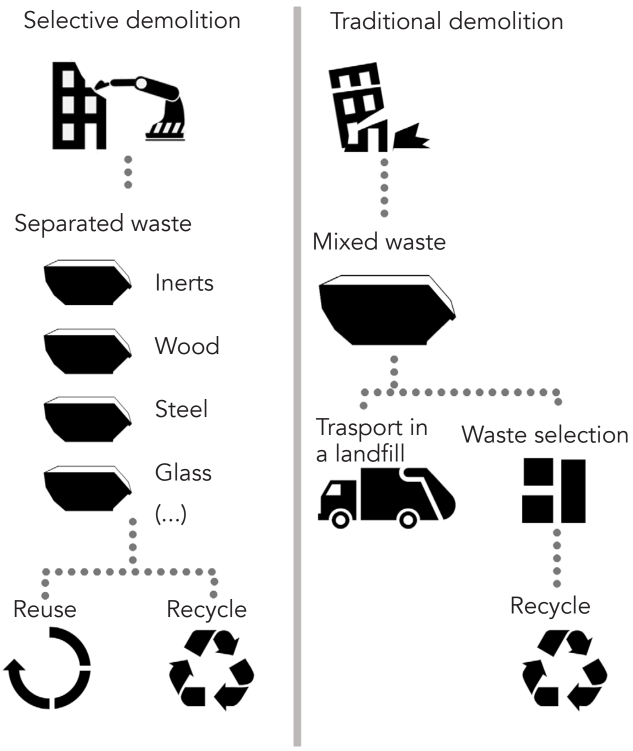


Fig. 3 _ Comparison between selective demolition and traditional demolition

The selective demolition, in fact, does not require the use of specific, predetermined instruments and consequent methods of demolition.
Rather implies procedural stages carried out through the use of different means, which allow the division of the building material into homogeneous categories, and preserves the integrity of the elements.
Thus it is possible to improve the recovery and recycling.
Therefore, the tools and methods of demolition depend on the boundary, structural conditions, and state of preservation.
The relationship between the demolition tools, solicitation or induced action, the advantages and disadvantages is shown below.

Instruments	Actions	Prevalent use	Advantages	Disadvantages
Explosive	Impact	Total demolitions	- Speed of execution	- Heterogeneous material fractions - Need of safety of the area. - Poor versatility - High pollution
Steel sphere (disused)	Impact	Total demolitions	- Speed of execution	- Heterogeneous material fractions - Need of ample area - High pollution
Bucket	Impact	Total demolitions	- Speed of execution -Mechanical arm with high extension - Top action	- Heterogeneous material fractions - High pollution
Hammer (pneumatic or hydraulic)	Impact	Total and partial demolitions	- Good versatility - Speed of execution	- High mechanical vibrations - High noise pollution
Hydrodemolition	Impact	Total and partial demolitions	- High versatility	- High cost - Average time
Expansive mortars	Impact	Demolitions of concrete	- Minimal environmental impact	- Poor versatility
Coring machine	Impact	Demolition of large thickness and /or against ground walls	- High penetration thickness - Good accuracy - Average cost	- High noise pollution - Average versatility
Shears	Impact	Total and partial demolitions	- Speed of execution - Lateral action - Good accuracy	- Mechanical arm with limited height - Average pollution
Saw (disc or chain)	Impact	Partial demolitions in case of cutting of walls.	- High accuracy - Low vibration - Low pollution of dusts	- Long-time average - Average cost
Diamond wire	Impact	Partial or total demoliions in casse of cutting of building	-Discreta accuracy -Stroke average	- Poor versatility
Pliers	Compression	Total and partial demolitions	- Speed of execution - Lateral action - Good accuracy	- Mechanical arm with limited height - Average pollution - Poor versatility
Thermal nozzle (gas torch)	Thermal action	Matal cutting	- High precision - No mechanical effects in building - Low environmental pollution	- Poor versatility - High cost
Manual instruments	Impact, cut, comprssion	Total and partial demolitions	- High accuracy - Homogenous and integrates product fraction - High flexibility - Low environmental impact	- Average-long time - Average costs

The advantages and disadvantages described in the table are generally valid, considering that the demolition takes place using only the specific tool described.
When tools and techniques that increase the speed of execution of demolition are used, it is more difficult to collect homogeneous categories, unlike when the deconstruction happens with more time. Therefore, the demolitions carried out with explosives, the steel ball and the bucket have been traditionally used without attention given to the possibilities of reuse/recycling of components, while the publishing of a deconstruction manual has encouraged the development of new life cycles.
Currently; however, we are witnessing a research of combined methods that preserve the integrity of elements and the division in homogeneous categories. This in turn increases the rapidity of execution of demolition.
One of the reasons for this attitude can be found in the increasing presence of regulations aimed at reducing waste, and consequently, also at the selection of materials.
An extension to the traditional demolition for the need to separate materials into homogeneous categories, after the demolition or when it is more complex, is also introduced.The act of demolition, in fact, undoubtedly requires shorter time in the case of traditional demolition, which is generally equal to half compared to selective demolition. However, if the evaluation is made as a whole, i.e., the sum time for the demolition and sorting and the time between the traditional demolition and selective demolition, then the time becomes comparable. Consider, for example, the logistical difficulty and the time needed to perform a traditional demolition. The division from the rest of the debris of materials crumbles as easily as the insulation or drywall. To obtain a quality product from this case, it is necessary to transport materials to plants that are provided with equipment capable of separating the materials, with subsequent economic and environmental charges.
Therefore, it is clear that the search for selective demolition methods must combine with the use of mechanical hand tools.
It arises from the need to reduce the timing of the construction site and the costs of landfill and, at the same time, increase the percentage of recoverable materials.
The use of mixed techniques can be used even when the building has significant structural problems that would compromise the safety of workers in the event of deconstruction phases of the load-bearing part.
This is the case of the selective demolition, carried out in the Municipality of Ocre, a hamlet in the province of L'Aquila[7] of a post-war building that had been severely damaged by the earthquake.
First, they removed the hazardous materials and all-moving parts: doors, railings, insolation, etc.
Then, there was a controlled demolition with category II micro explosives.
Approximately 150 micro explosives, for a total of about 8 kg, have been used with 80 detonators offset by 25 milliseconds of each other, along with 100 detonating cords.
The area has been restricted and banned for 150 metres around the building. The arrangement of micro explosives favours subsidence own of the building. The vibration were measured with 3 seismographs placed in 3 buildings that were closer. The highest value is around 4 mm/s. International laws provides that the neighbouring buildings bear up to 18 mm/s.
A sorting on the ground of materials, such as tiles, was subsequently carried out, which for safety issues could not be previously recovered. In the selective demolition, the site organization is strongly influenced by the distance of the neighbouring buildings and roads present. In general, the need to separately store multiple materials requires the presence of appropriate areas and their organization, as a function of the phases of demolition and of the quan-

Fig. 4 _ Demolition with explosive charges (AQ) tity of materials present. In view of the Italian building and most used construction techniques, the area of greatest dimension will have to be that intended for inert waste. The areas and the methods of storage must be identified taking into account the following:

- the amounts and types of materials,
- the interference of simultaneous processing,
- the height of the storage with the aim to prevent tipping and overlapping,
- the viability of the site and accessibility,
- the paths for load handling,
- the distance from precarious situations (for example the edge of the excavations near the building).

With the aim to avoid the double operation of depositing and subsequent loading for transport, it is possible to directly store the demolished materials within roll on/off containers. In such a case it is appropriate to consider the standard dimensions of containers within the site organization. They vary depending on the nominal volume, with a maximum value of 40 mc.
While stressing that every building needs a programming of the demolition on the basis of the boundary conditions (time of demolition, climate, neighbouring buildings, etc.) that the inherent characteristics (n° of floors, building system, % material fraction, etc.) of the same selective demolition are based on specific and progressive stages.
At first, it is necessary to proceed to inspections designed to detect the construction equipment and the evolution/ variations of the same with respect to the initial configuration. The decomposition technology is indeed necessary to identify the modes of demolition to ensure the separation of homogeneous categories.
The construction equipment is assumed on the basis of the time of creation and, consequently, on the assumption that the building was built with a specific construction system. In Italy, especially for the buildings constructed before the obligatory deposit under Llaw 10/91, which is not subject to historical-artistic restrictions, it is appropriate to proceed with punctual destructive tests in order to verify the correct stratigraphy. That is to plan the demolition and define the end-of-life scenarios of materials actually present in the building.
Sometimes the building may have only partially changed. The essays do not provide enough information.
For this, the phase programming of demolition, even if well-defined, must guarantee suitable flexibility. In fact, in the separation of materials, the lack of attention in one of the phases can invalidate the work performed in the previous steps.
The level of degradation and the residual performance affect the chances of reuse. Preliminary analysis allows the planner to attentively evaluate the convenience for the integrity of the material. One example of this would be a wooden beam whose degradation prevents a structural reuse.
Assuming that it is recycled for the production of particle boards, it will not be necessary to ensure the integrity of the beam itself during disassembly, which aids in the demolition speed.
According to the ANPAR study, the maximum distance that waste has to travel from the place of production to point of treatment, with the aim to make this operation convenient, is equal to 40 km.
Therefore, according to the treatments plants present in the area, the end-of-life scenarios for the materials can be evaluated more expediently, compared to the most commonly identified method of demolition.
In general the selective demolition must be carried out with progression from the top downwards.
Typically, the removal of hazardous materials/components before starting demolition must be carried out. First, the crew proceeds with the disassembly of internal mobile components that can be removed "without destruction," such as doors, radiators, switches, sockets, sanitation, etc., and disassembly of the external components of similar nature as shutters, fixtures, gutters. Then it proceeds to the removal of the floorings and tiles. The next phase involves the demolition of internal partitions, the cover and the external cladding and floors. These phases also proceed to the progressive demolition of the plants, whose pipes pass in the wall. At the end, the supporting structure and foundations are demolished.
There is a relationship between the integrity of the components and the stages of demolition. It shall be taken first to the deconstruction of the parties whose members can remain intact and after, while remaining high homogeneity within the categories, which progressively decreases the integrity level of the elements.
The attention to the relationship between the phases of demolition and the integrity of the materials/components, ensures second raw materials of a good quality.
The integrity of the components depends on the technique of the deconstruction, the construction system and on the materials used.
For example, a masonry built with solid bricks, theoretically can be broken without attention to the integrity of the elements, i.e. through shock leading to crushing of the elements and obtaining a material mixture of bricks and mortar. It can also be deconstructed by manually removing the individual elements and obtaining two distinct product fractions and reusable bricks.
The latter method is usable only when the mortar does not have the firmness to prevent the separation between the elements.

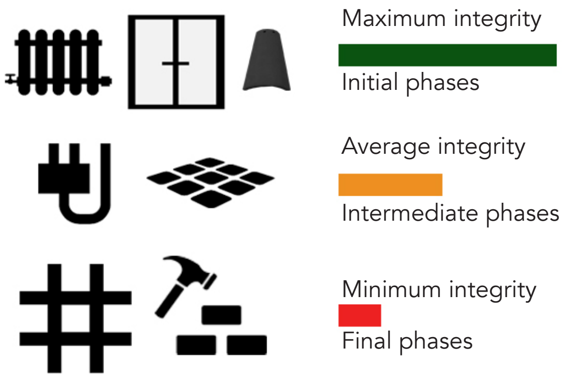


Fig. 5 _ The relationship between the phase of demolition and the integrity of the elements

Fig. 6 _ Residenze Taviel, deconstruction for each floor

Fig. 7 _Residenze Taviel, manual deconstruction of the wall

Fig. 8 _ Residenze Taviel, manual cleaning of the bricks

Fig. 9 _ Centro Porretta Terme, aggregate storage area

One of the first European examples of selective demolition was carried out as part of the recovery of the "Residenze Taviel" in Saint Omer in France[8]. The complex was built in the 16th century to accommodate a hospital for women in need. In the 17th century it was transformed into a prison until 1990. In 1997, it was recovered and turned into 49 social houses, with the aim of repopulating the city centre. The project of Grobelny and Carlier, keeps the volume of the building complex, but the perimeter wall was demolished to make a garden.
The contractor was a laboratory of social reintegration. Thirty-five people worked on the deconstruction of the complex by recovering and making an inventory of the following material: electrical wiring, ducts, copper pipes, wooden floors and trusses. The inventory also estimated 1.2 million bricks, of which 30% remained intact after the deconstruction operations. 4,000 bricks were reused in the reconstruction project and the remaining were sold.
The cost of deconstruction was 350,000 FTTC. The recovered materials include: 89,000 yellow bricks, 310,000 red bricks, 17 trusses, 483 metres of elm planks and beams, 8.5 cubic metres of different wood, 19,350 units of slate, 252 square metres of stone flooring, electrical and sanitary material.
Another selective demolition was carried out within the reconstruction of the Centre for the elderly in Porretta Terme, which was the former Ferrohotel. It was made by the CISA in agreement with the city municipality[9]. It was built in the 1970's and was used as a dormitory for staff FF.SS.
The building consisted of residential modules composed of rooms with an attached bathroom and the building included a mezzanine for common services (toilet, kitchen, dining hall) on the first floor. The pitched roof is asymmetrical.
The project provides for distribution of the Senior Centre on the first floor with an extension for service locals.
Construction plans for the first floor will be the construction of offices for the locations of cultural associations.
The project, carried out in 2007, provides numerous interventions aimed at a new spatial distribution, seismic adjustments and improving energy efficiency, both in terms of plants (plant upgrades and using renewable energy resources) and housing (external insulation of the perimeter walls and insulation of the attic floor).
The demolition of all internal dividers and plasters, as well as demolitions of gates for opening new entries and removal of existing plants.
The selective demolition of the building required a programmed organisation of the site, with the aim of temporarily storing the material for homogeneous categories to facilitate the start for reuse/recycling.
The demolition stages took place in a planned order for the building, with the purpose of optimizing the times to simultaneously recover materials present.
From the month of November, they concurrently performed demolition works and structural adjustments, while working on different portions of the building.
The following list shows the order of operations involving only the selective demolition.

N°	Processing	Euros
1	Removal of plants present in the area.	240,00
2	Demolition of the steel portal and removal of the tank.	---
3	Removal of the electrical equipment (cables, switches, light fixtures, chandeliers, etc.)	---
4	Removal of doors and interior sub-frames.	3200,00
5	Removal of bathroom fixtures.	2014,00
6	Removal of radiators.	1650,00
7	Removal of central heating installation.	380,00
8	Demolition of internal masonry.	16544,00
9	Demolition of internal ceramics liners.	1064,25
10	Demolition of floors and substrate bedding.	5250,00
11	Removal of pipes of water-sanitary systems and of heating.	---
12	Cutting the sandstone pallets.	120,00
13	Elimination of interior plaster.	16181,44
14	Demolition of the outer sandstone coverings.	1584,00
15	Demolition of the lower outer wall in concrete blocks.	1363,00
16	Demolition of the external steps, landing, and guard.	520,00
17	Demolition of the chimney.	750,00
18	Demolition of 2 fiberglass boxes.	---
19	Partial demolition of the existing floor in beams type Varese and hollow clay tiles for structural adjustment.	---
20	Removal of roof covering in tiles of sandblasted.	---
21	Elimination of external plaster.	---
22	Opening or modification of openings.	---
23	Complete removal of the exterior doors.	---
24	Opening or modification of openings.	---
25	Partial demolition of existing floors.	---

Fig.10 _ Centro Porretta Terme. Within some walls, glass fibre insulation is present, which was not seen in the survey carried out in the preliminary phase.

Fig. 11 _ Centro Porretta Terme. Demolition of flooring and subfloor with a jackhammer.

Fig. 12 _ Centro Porretta Terme. Reuse of the joists in the new horizontal structure

Fig. 13 _ Centro Porretta Terme. Removal of the roof covering, which is necessary to isolate and waterproof the roof. The tiles are stacked on the roof and then reassembled.

Fig. 14 _ Centro Porretta Terme. Removal of plaster on the outer portion of the wall, where the building expansion was made.

Fig. 15 _Storage after deconstruction performed by the Rotor group

An important project from a methodological point-of-view is the European project VAMP[10] (Valorizzazione Materiali e Prodotti di Demolizione) that was created between 1990 and 2000. The project manages waste from C&D, which helps companies to locate the destination of materials and waste components and to select recycled materials to be used in the site that have been offered by other companies. As a result, companies or individuals can receive free software from the online registration to identify potentially reusable materials and components and draw up a plan to demolish.

The software is connected with the database, which helps to identify where to take the materials and the components previously identified.

After defining the breakdown of the building, the evaluation of residual materials/components is carried out according to five characteristics [11]:

- functionality: the capacity of the component to meet the typical functional performance that does not distinguish the nature of its own function;
- appearance: analysis of the surface to verify the presence of degradation no higher than those caused by normal wear;
- geometry: analysis of the changes and deformations of the geometrical characteristics which must not be greater than those caused by normal wear;
- merit: analysis on the "antiquity" and marketability of the element;
- evaluation for aggregate component: a rough evaluation that takes into account both the component in its aggregate form (e.g., in a wall the weaving), and the single element in its disaggregate form (e.g. in a wall, the single brick, to which the residue performance criteria is applied as set forth in the remaining cards).

Thus it is possible to assess the stages of demolition benefitting the components that have the highest residual performance.

From an operational point of view, the work done by the group Rotor[12], is relevant. Since 2005, Rotor has analysed the flows of waste from construction and demolition in Brussels, conducting analysis on about n.80 construction sites. The study is aimed at defining the practices of reuse. In fact, Belgium, boasts good recycling practices, but the latter is a partial answer to the problem of unsustainable waste. Recycling operations often require a considerable input of resources, along with the loss of intrinsic and primary properties of the material.

The Rotor group study places the focus on conditioning that the time of demolition/construction has on the adoption of a correct methodology of deconstruction.

In fact, the need to begin the rebuild in a short time often comes at the expense of a demolition that is attentive to reuse of materials.

Some experiences in the United States, for example, show that legislation enables the activities of dismantling before obtaining the demolition permit favouring the recovery of higher quality materials.

In addition, they analysed scenarios for end-of-life materials mainly used in construction with attention to the specific area conditions.

3.3 _ Case study: experimentation in the Valencian Community[13]

Currently, new organisations can recognize the evolution of the concept of selective demolition.
An investigation in Spain, for example, found a reconfiguration of construction companies with a particular enrichment of skills that enhanced the economic benefit of material reuse. The companies that deal with the deconstruction, in fact, also open a niche market of products derived from demolition. This is going to build a "short chain," where products of demolition, generally carried out in the territories of belonging to the enterprise, are stowed in local stores so as to limit the impact of transport. It sets up an innovative approach that helps to offset the economic limits of the selective demolition, which triggers types of materials and components in a new local green economy. Spanish legislation has certainly contributed to the development of the market for secondary raw materials by increasing the landfill costs. According to market prices provided in IVE 2015 of Valencia, charges to landfills of undifferentiated material amounted to about double of charges of homogeneous categories.
The legislation has also stimulated practices of building regeneration, which sometimes require obligatory interventions of demolition. The Real decree 8/2011 requires a technical inspection in buildings with antiques over 50 years old and, depending on the conditions of degradation detected, must carry out recovery works more or less relevant.
A selective demolition in the village of Massamagrell, near Valencia, had been carried out[14], using deconstruction techniques in order to guarantee the resale of the materials by the same company in the near village of La Pobla de Farnals, located at a distance of about 1.5 km. The building, constructed around 1930, is spread over two floors and has a footprint of 80 square metres with a face width of 6 m. With the neighbouring buildings it formed a continuous front and shared the two side walls with them. The presence of a continuous front was a further incentive for the demolition manual, because it increased the safety of neighbouring buildings. The initial phase of the demolition contained the performing of tests for identifying the construction equipment and the presence of critical issues in order to secure the safety of the operation. In particular, the wooden beams were punched with a steel shaft to verify the integrity and the absence of biological degradation. The vertical closures were made with plastered solid bricks, the intermediate horizontal closure was made with wooden beams with laterally nailed wooden elements supporting brick vaults, which act as formwork for the concrete filling. Above it, decorated floor tiles were placed. The pitched roof was made of wooden beams with wooden joists that support the bricks and roof tiles. A false ceiling made of local woven reeds was hung at the wooden beams. Interior partitions were made of plastered solid-cut bricks.
On the first floor, the presence of two additions added later, that at the time of demolition, were dangerous, due to the low anchoring with the original building.

Fig. 16 _Storage of doors inside the deposit of MERCADERRIBO company located in Valencia

Fig. 17 _Front view of building located in Massamagrell

Fig. 18 _Rear view of building located in Massamagrell

Fig. 19 _Demolition of internal partitions with a hammer

Fig. 20 _Demolition of the additions.

Fig. 21 _Initial phase of dismantling the roof.

After the preliminary tests, the demolition was made according to specific steps, in order to optimize the time and to ensure the safety of the workers.

First, the external components of the electrical system (switches, sockets etc.), interior doors and bathroom fixtures (sinks, toilets etc.) were removed. Next the original flooring, consisting of cement tiles, was removed. The presence of mortar on one side of the tiles made them easily reusable. After the transport to storage, the tiles were cleaned. Moreover, the historical importance of the tiles designates a higher market value and greater revenue for the company. Subsequently, the false ceiling of the horizontal closure was disassembled. The reeds were piled separately to be delivered to another company that handles recycling.

Later, the company proceeded to create holes in the intermediate horizontal closure, taking care not to damage the wooden beams. The holes were aimed to place the undifferentiated debris, arising from demolition in the lower level. The next step entailed the demolition of the interior walls of the upper floor using hammers.

The recovery of the bricks occurred only partially due to the difficulty of manually demolishing the wall without causing their destruction and for the time needed to clean the mortar and plaster on all sides, which made it not convenient from an economic view. Therefore, the solid bricks were recovered only when they contained mortar on one side. Once the debris from the floor was cleared, the demolition of the two additions that there were on the first floor became possible.

The danger of the additions made the operators pay attention to safety by preparing harnesses connected to the structural elements of the building. The fixtures and wooden shutters were first removed. Then the roof made of steel sheet panels; finally, the walls made of hollow bricks were demolished. The demolition of the walls to the additions was made by overturning their planes, which was encouraged by the mechanism already in place.

After the previous demolitions, scaffolds were mounted to the roof. An opening in the roof was made to facilitate access. Starting from the outermost layer, the ducts, tiles, bricks, wooden joists, wooden beams and ridge beam were removed. All components were recovered. After removing the railings on the first floor, the upper masonry facade was demolished. Even in this case, the same considerations were made regarding the difficulty of the reuse for the bricks that constituted the internal partitions.

As the demolition of the first floor ended, the company then proceeded tto the progressive deconstruction of the intermediate horizontal closure, starting from the most distant part from the scale. For the ground floor, the demolition process was similar, namely the steps for the deconstruction of the internal partitions, the removal of fixtures, windows, and the walls, both scale and perimeter.

On the ground floor, there were walls with newer tiles. The non- historicity of these elements, and the strong anchoring of mortar, did not make had the reused convenient in terms of time.

With the demolition of the walls, the pipes were separated from debris. They can be reused when intact. Otherwise,

they are recycled. The demolition was carried out completely using non-electric hand tools (hammer, saw, chisel, etc.); only the removal of the stranded debris (consisting of bricks, mortar and plaster) had been made using mechanical tools at the end of the demolition.
The small size of roadway and the shape of the lot necessitated the progressive transport of recovered materials from the deposit of resale of the company, because the piling of the construction material was possible only for a limited amount.
The materials that can be reused are listed below:

- n. 1700 solid bricks 25x25x12 cm,
- n.1800 roof tiles,
- n.270 solid bricks 5x25x12 cm,
- n.900 decorated cement tiles 20x20x2 cm,
- 2.4 mc wooden beams with section 17x7 cm (roof) and with section 22x7.5 (floor),
- 210 ml of wooden joist with section 6x3 cm,
- 0.5 cubic meters of wooden beams with section 17x25 cm,
- n.2 window with two wooden door leaves,
- n. 1 wooden door with two door leaves,
- n.1 wooden door with one door leave,
- n. 2 wooden windows with two door leaves,
- n.3 wrought iron railings.

The amount of material disposed of at the landfill was only about 85 cubic meters.
Therefore, 22%[15] of the materials resulting from selective demolition can be reused, with the remainder given to the landfill. Recycling scenarios will be considered depending on the quality and homogeneity of the material fraction. The amount of demolition time made with two skilled workers totalled 7 working days.

Economic assessment[16]

The selective demolition has reduced the quantity of material in the landfill (85 cubic metres), consisting of a homogeneous material fraction attributable to CER code 170100.
The transport and landfill cost of this material is approximately 820 euros. If a selective demolition is carried out and the materials are not reused but landfilled, the end-of-life cost amounts to almost 1050 euros.
Finally, if a traditional demolition is performed, without separation of the materials in homogeneous fractions, the landfill cost for 109 cubic metres of waste is approximately 1800 euros. In addition to these costs, the cost of the workers and machinery rental must be added. In the case of a selective demolition we have to consider 1 site director and 2 skilled workers for 7 working days and the rent of a bulldozer for 4 hours, for a total of about 3050 euros.
Unlike in case of a traditional demolition, we have to consider the cost of 1 site director and 2 skilled workers for 2 working days, the rent of an excavator with hammer for 1 working day and the rent of a bulldozer for 1 working day; the cost is approximately 2000 euros. Similar processing costs for both the demolition (supply and installation of yard fencing, signage etc.) are approximately 250 euros.
The total company cost for the selective demolition case

Fig. 22 _Demolition of intermediate floor

Fig. 23 _Debris removal with mechanical means

Fig. 24 _Area after the demolition

amounts to 4090 euros, while the same demolition made with traditional method costs 4050 euros. The traditional demolition and selective demolition have a comparable cost. However, we have to consider that in the traditional demolition, the time gained by the company can be used in other jobs. The resale of materials will help to recover the full costs incurred for the selective demolition and to obtain a greater gain. Considering the market value of these materials in the territory near Valencia, the selective demolition produces a profit gain of about 93% compared to the earnings obtained from the traditional demolition. This gain offsets the extra time required for the selective demolition, which amounts to 5 days.

Environmental assessment[17]

The selective demolition causes an environmental damage approximately equal to 3.3 tons CO2-eq, including 1 ton CO2-eq for the transport of materials to storage and the landfill, about 0.4 tons CO2-eq for the use of the bulldozer in the final part of demolition, and almost 1.9 tons CO2-eq resulting from the lack of reuse and the landfilling of 85 cubic metres of material (bricks, mortar, and plaster). We can also consider the environmental damage that results from the need of to produce new materials, since the recovered materials have been transported to the landfill, which is approximately equal to 37 tons CO2- eq.

The environmental damage from a traditional demolition of the same building; however, would approximately amount to 6.3 tons CO2-eq. Included within that total is 1.2 tons CO2-eq for the transport of materials in the storage and in the landfill, about 2.8 tons CO2-eq for the use of machinery in the demolition (bulldozer, demolition hammer, and demolition grab) and about 2.3 tons CO2-eq caused by the non- reuse and the landfilling of about 109 cubic metres of materials. We can also consider the environmental damage resulting from the production of the same amount of material that is not reused, which is approximately equal to 48 tons CO2 eq.

Therefore, if we consider the environmental damage resulting from the demolition, the transport and the landfilling, the selective demolition has a lower environmental impact of 47.6% versus the same demolition, if it is completed in the traditional way. In this case, the portion of materials that cannot be reused is produced *ex novo*, using materials that perform the same function as discarded materials, but that are more sustainable in accordance with the techniques currently used. Otherwise, if it is assumed that both in the case of selective demolition and traditional demolition, that the portion of materials cannot be reused is identically produced *ex novo*, the selective demolition has a lower environmental impact of approximately 25.8% compared to the traditional demolition of the same building.

For a comparative purpose, we also consider the case where we proceed to remove the plaster in the walls and manually deconstruct the brick by gradual removal of the mortar from the top to the bottom of the wall. Even in the case of a demolition with entirely manual techniques that require a longer lead time, we have to consider that the percentage for the integrity of the bricks is equal to 60%.

The time required for the demolition, in this case, is approximately equal to 25 working days with 2 skilled workers.

The environmental impact of an ideal selective demolition that completely saves the building materials, even if the execution time is greater, amounts to 2.3 tons CO2-eq, for which about 0.6 ton CO2-eq for the transport of materials in the storage and in the landfill, about 0.5 ton CO2-eq for the use of mechanical equipment in the deconstruction, about 1.2 tons CO2-eq caused by the non-reuse and the landfilling of about 34 cubic metres of material consisting of bricks, mortar and plaster. If we consider the new production of materials that cannot be reused, the environmental impact of this production is approximately 22 tons CO2-eq.

Therefore, considering only the impact of demolition and landfilling, the ideal selective demolition (which almost completely reuses the materials) has a lesser environmental impact by about 30.3%, compared to the selective demolition performed. It also has a lower environmental impact of about 63.5%, in contrast to traditional demolition.

Otherwise, considering the impact of the new production of non- reusable materials, the demolition, and the landfilling, the ideal selective demolition has less environmental impact of about 39.7% than the performed selective demolition and a lower environmental impact of about 55.3% compared to traditional demolition.

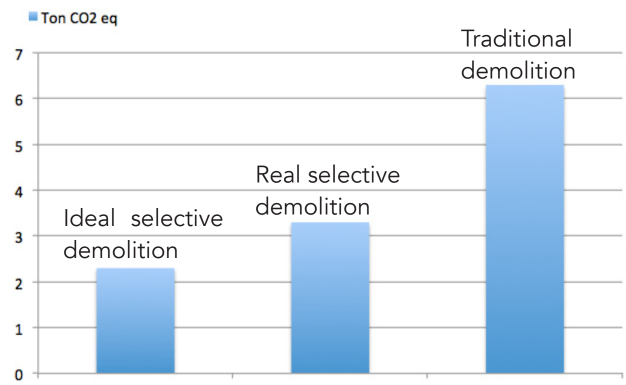


Fig.25 _ Environmental impact including machinery, transport to the landfill or storage and disposal.

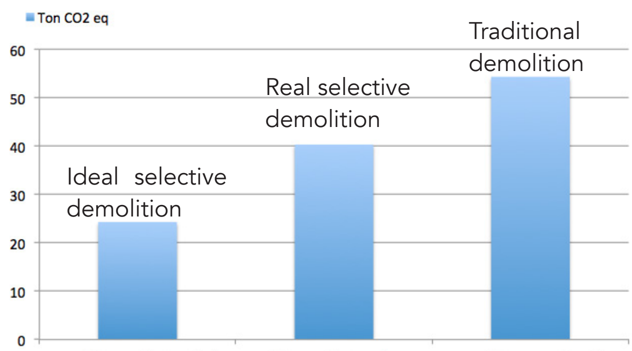


Fig.26 _ Environmental impact including machinery, transport to the landfill, storage, disposal and the new production of the materials that cannot be reused.

The convenience of selective demolition

The assessments illustrate the cost-effectiveness and environmental impact of selective demolition.

The economic convenience is strongly increased by the resale of the material. Consequently, the development of a market for reused materials is a prerequisite for encouraging voluntary mechanisms of selective demolition. It is clear that the price of reused materials has to be competitive with the price of new materials, including the cost of transportation and any cleaning or reconditioning. For example, the resale of hand-painted ceramic tile that has a historic-artistic value can be sold at a price even higher than an industrially manufactured tile that is normally present on the market. Therefore, the cost of cleaning is compensated by the historical and artistic value. The resale of used industrially manufactured tiles without a particular value has to be a lower price than the same product that is new. The cost of cleaning, especially when the mortar is present on more than one side, is often greater than the new production cost of the component, resulting in a lack of convenience for the resale. Also, in the described example, the execution of the demolition in a site that is at a distance of 1.5 km from the resale storage minimizes the incidence of the transport costs on the resale price.

Therefore, the development of a market of reused materials and secondary raw materials is influenced by the cost of these new materials, by the cost of reconditioning operations and by historical or artistic value.

The selective demolition is itself a noble, sustainable action because it allows us to recover or recycle the materials and reduce the impact of transport and landfill disposal. The environmental convenience comes mainly from the lack of necessity to produce new materials due to reuse of the same materials. Higher is the recovered fraction and greater is the convenience of reuse. In the described example, the environmental convenience is increased by reducing the impact of transport from the site of demolition to the place of reconditioning and resale or by limiting the interventions to a local level.

Although some materials are not reused because faster manual demolition techniques are prioritized. The homogeneity of the fraction allows for the acquisition of secondary raw material of good quality through recycling.

Assuming the need for the building regeneration, based on policies aimed at reducing the consumption of land and resources, in some cases, it is necessary to do a partial or total demolition.

The achievement of a balance between affordability and sustainability, as in the case of described selective demolition, is the first step in encouraging voluntary mechanisms for the reuse of materials. This will trigger honourable processes, both in the field of demolition and in the market of building materials.

The strength of the described process is the dependence of the economic and environmental convenience from operating at the regional level, thus causing progressive urban regeneration in the contemporary development of a local sustainable supply chain based on closed cycles of matter.

NOTES

1. *Life APPRICOD*
2. *Centro Interuniversitario di Valutazione Qualità del Costruito del Politecnico di Torino*
3. *Elementi chiave del settore del riciclaggio dei rifiuti da costruzione e demolizione ANPAR*
4. *Vocabolario Treccani*
5. *Phare Twinning Project RO2004/IB/EN-07, Guidelines on ind. C&D Waste XX*
6. *Data from Phare Twinning Project RO2004/IB/EN-07, Guidelines on ind. C&D Waste XX e rielaborati.*
7. *Ricostruzione.soalco.it*
8. *Costruire in laterizio 65, "Residenze Taviel a Saint-Omer. André Grobelny, Pierre Louis Carlier", Jeanne Le Page, pp. 344-347*
9. *www.centrocisa.it*
10. *Developed in the "Programma LIFE-Ambiente dell'Unione Europea, dalla Regione Emilia Romagna nelle Province di Modena e Reggio Emilia" with the technical support of ICIE*
11. *www.webgis.csi.it*
12. *rotordb.org / Abitare n.517/2011*
13. *Esempi di architettura, vol.2, n.2, 2015 "Urban Renewal: from Demolition to Regeneration. Economic and Environmental Conveniences" Stefania De Gregorio, pp. 95-102*
14. *The selective demolition was made by company MERCADERRIBO, Avenida Aragón, 37 ctra. CV-300 La Pobla de Farnals.*
15. *The percentage evaluation takes into account the cubic meters of materials.*
16. *The costs of transport (<20 km), landfilling, and the costs of workers and rents are calculated according to market prices in the IVE 2015 of Valencian Community. The prices are referred to the "PEM (presupuesto ejecución material)," and are considered minus general expenses (generally 13%), company profit for (typically 6%), and IVA.*
17. *The environmental damage has been calculated with IPCC2007, 100 year method, ECO-it 1.4.*

PHASE 3_ Specific analytical learning phase. Characterization of waste elements arising from the selective demolition of safety systems in L'Aquila.

The third phase is about the specific case of rebuilding in L'Aquila, which contain the definition and analysis of systems used for the safety of damaged buildings. The quantitative data, needed to assess the extent of the problem, are derived from the costs incurred by the government for safety operations in the entire area around the seismic crater. The systems are classified according to the contrasting mechanisms, which are important in the reconstruction for the proper coordination between disassembly and consolidation operations. Then we analyse the construction systems used and identify the dimensional characteristics and weight of all the elements that compose them. The availability of an abacus of reference allows us to quickly locate properties of elements and design reuse according to them. For each type of system used, assessments are made in reference to reversibility, flexibility and ease of assembly/disassembly. In addition to promoting the correct identification of disassembly, this data is used to decide whether to reuse the construction system and its elements in the manner of origin, i.e. the function for which they were originally placed on the market or whether to find more compatible ways to reuse residual performances arising after the first use.

The comparison between the characteristics of various systems also makes it possible to evaluate, for purposes of a subsequent reuse, the opportunity to associate a particular system to a specific intended use, such as identifying the main categories of reuse as temporary or stable.

We present and analyse from a technological point of view international projects in the field of building regeneration or temporary structures to find an innovative and noble method. The described projects use components similar to those used for the safety systems in L'Aquila and present with them typological dimensions, geometric or textured similarities. The research and analysis provides interesting ideas for design reuse. They also identify the relationship between building systems and destinations of use, with particular regard to the correlation between the achievable performance thanks to the system, and the priority requirements for a specific function. It is also possible to establish a correlation between the construction system and the formal architectural possibilities.

Therefore, the outcome of the specific analytical learning phase is the knowledge of technological potential and composition of the elements arising from the selective demolition of safety systems in L'Aquila.

4 _ SAFETY SYSTEMS IN L'AQUILA

4.1 _ Costs of temporary safety systems

The temporary safety systems were provided and set in place by firefighters, mainly in wood and with polyester bands and the remainder from private companies through public procurement tenders. However, in procurement contracts it is expected that the safety systems are purchased rather than rented. Therefore, municipalities at the moment of settlement essentially become owners in all respects of the provisional works on the territory. The analysis of the amounts paid by the government to companies that have dealt with the safety of buildings made it possible to identify the public capital invested for each municipality contained within the seismic crater area[1].

Each intervention has been taken into account and recorded by the company, including the type of provisional work, the location by address, the date of execution of the work, the amount paid and to be paid and the settlement date with the SAL reference. A total of about 212 million euros was spent for the well-being of all of the unsafe buildings in the seismic crater in L'Aquila. The municipality where they made the largest number of interventions is L'Aquila: about 900 interventions for a total of approximately 188 million euros. In other municipalities of minor extension, the number of interventions and consequently the costs of safety are considerably reduced.

They spent about 4.5 million euros in Paganica, 3 million euros in Bagno Piccolo and Bagno Grande, 2.5 million euros in Coppito, in Tempera, Roio Poggio, and Bazzano about 1.6 million euros each, 1 million euros in Collefracido and San Gregorio and finally about 1 million euros were spent in the other municipalities and villages.

The temporary safety systems consists mostly of tube-joint systems, multi directional systems, steel profiles and cables, modular towers, prefabricated wood systems and mixed systems.

Through numerous inspections carried out on site, it was possible to qualitatively define the percentage of safety systems, namely:

- shoring with the use of timber: 10%,
- shoring with tubular elements and steel clamps: 30%,
- shoring and hoops with structural steel profiles: 30%,
- polyester ratchet bands: 5%,
- shoring of floor with steel and wood: 15% (which was considered a share of 9% for steel and a share of 6% for wood),
- shoring of openings with steel profiles: 4%,
- shoring of openings with wood elements 6%.

These percentages were applied to the total expenditure that each municipality has carried out for the safety of buildings, therefore obtaining the expense for each type of safety system. Subsequently, using the "Prezzario Regionale della Regione Abruzzo 2013" (Price list of Abruzzo Region 2013), the unit process of used systems was derived [2].

Dividing the total spending that each municipality has carried out depending on the type of safety for the unit cost, as defined by the price list, it delivered the quantity of materials (wood, steel, and polyester bands). The use of the 2013 price list makes the calculation of the approximate amount of materials at fault because the updating of prices took place when the earthquake occurred in the year 2009, which led to an increase in the unit cost. In addition, the volume of work is not considered in the estimation as it has a higher unit price depending on the function of the contained quantity of work.

In light of the made calculations in the municipalities of the territory of L'Aquila for the safety of the buildings they have been used with approximation at fault:

- 47.100.000 Kg of wood
- 19.400.000 Kg ol steel
- 440.000 ml of polyester bands.

Municipality	Cost of safety system Euros	Wood (boards, elements) Mc	Wood to prop floors Sqm	Wood to prop openings Sqm	Steel tubulars Cad	Steel profiles Kg	Steel to prop floors Sqm	Steel to prop openings Sqm	Polyester bands Ml
L'Aquila	188.096.424	24.755	51.810	164.997	2.048.981	6.749.872	77.715	72.254	393.080
Arischia	35.730	5	10	31	389	1.282	15	14	75
Assergi	449.150	59	124	394	4.893	16.118	186	173	939
Bagno piccolo e grande	3.014.851	397	830	2.645	32.842	108.188	1.246	1.158	6.300
Bazzano	1.630.182	215	449	1.430	17.758	58.499	674	626	3.407
Camarda	429.068	56	118	376	4.674	15.397	177	165	897
Cese di Preturo	50.356	7	14	44	549	1.807	21	19	105
Civita di Bagno	625.917	82	172	549	6.818	22.461	259	240	1.308
Collebrincioni	625.917	53	112	355	4.411	14.532	167	156	846
Collefracido	1.014.222	133	279	890	11.048	36.369	419	390	2.119
Collemare	427.737	56	118	375	4.659	15.349	177	164	894
Coppito	2.519.748	332	694	2.210	27.448	90.422	1.041	968	5.266
Filetto	148.292	20	41	130	1.615	5.321	61	57	310
Gignano	366.236	48	101	321	3.989	13.142	151	141	765
Monticchio	546.394	72	151	479	5.952	19.607	226	210	1.142
Onna	70.444	9	19	62	767	2.528	29	27	147
Paganica	4.475.107	589	1.233	3.926	48.748	160.590	1.849	1.719	9.353
Pescomaggiore	17.251	2	5	15	188	619	7	7	36
Pettino	156.574	21	43	137	1.706	5.619	65	60	327
Pianola	258.633	34	71	227	2.817	9.281	107	99	540
Poggio S.Maria	38.981	5	11	34	425	1.399	16	15	81
Preturo	310.584	41	86	272	3.383	11.145	128	119	649
Roio Colle	65.088	9	18	57	709	2.336	27	25	136
Roio Piano	927.805	122	256	814	10.107	33.294	383	356	1.939
Roio Poggio	1.637.090	215	451	1.436	17.833	58.747	676	629	3.421
San Benedetto di Bagno	271.112	36	75	238	2.953	9.729	112	104	567
San Giacomo	27.673	4	8	24	301	993	11	11	58
San Gregorio	1.175.036	155	324	1.031	12.800	42.166	485	451	2.456
San Marco di Preturo	138.093	18	38	121	1.504	4.955	57	53	289
Sant'Angelo di Bagno	198.825	26	55	174	2.166	7.135	82	76	416
Sant'Elia	363.596	48	100	319	3.961	13.048	150	140	760
Santi di Preturo	40.037	5	11	35	436	1.437	17	15	84
Sassa	333.443	44	92	292	3.632	11.966	138	128	697
Tempera	1.647.296	217	454	1.445	17.944	59.113	681	633	3.442
Vallesindola di Bagno	151.668	20	42	133	1.652	5.443	63	58	317

4.2 _ The classification of temporary safety systems

The safety systems were put in place with the aim of preventing and combating any structural failure risks related to the damage found. It is possible to classify temporary works with respect to contrasting failure and/or function that are fulfilled in shoring, hoops, rods, liners and covers.

Shorings

The shorings may have a replacement, precautionary, or protective function (...) The proppant is realised usually from a mixed structure constituted from a damaged structure and from the shoring system working together(...) The shore in the earthquake is subject to vibrations,decompression, and detachment in danger of losing its position and fall, or hammering of the part it had to hold. To avoid these risks, it is necessary to bind it to the structure on which it rests[3]. They can be created with steel tubes connected by metal union joints, clamps or jaws, to form a lattice structure or wood material.

The "retention shorings" *aim to contain any failure that may occur with rotations or overturning of structural parts.*[4]

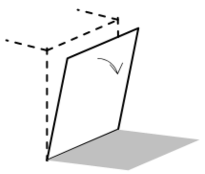


Fig. 1 _Kinematic mechanism of overturning or bulging that can be contrasted with retention shorings

They have the purpose of reducing the length of the wall elements that counteract the bulging of the wall towards the outside or prevent the tipping of the floor of the masonry wall due to cracks or compression at the union point of the perimeter or transverse walls.

Therefore, the oblique arrangement in contrast between the damaged element and the element of discharge generates a compression stress of props, which apply to an action with normal components to the plane of the wall.

It is convenient to place the props at the connection points between masonry walls, using horizontal elements (tables or vertical and horizontal currents) to ensure the load distribution.

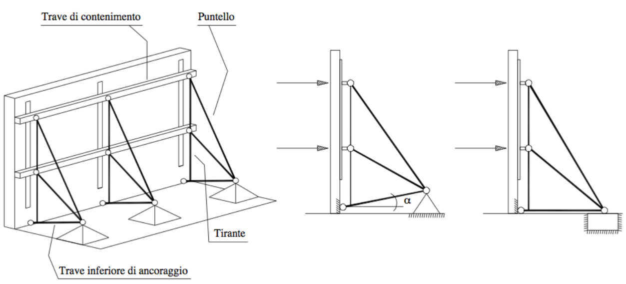


Fig. 2 _System scheme of inclined props

The base must have a remarkable capacity for resistance and rigidity to ensure that the system has the possibility to discharge the actions on the ground.

According to a construction scheme with a support base, the inclined props can be made when the area in front of the building is flat or crutch or when the area in front of the building is sloped or has scales.

In the first case, multiple props can be positioned both to converged beams and to parallel beams. In the second case, the props can be based both on a point and on a supporting area.

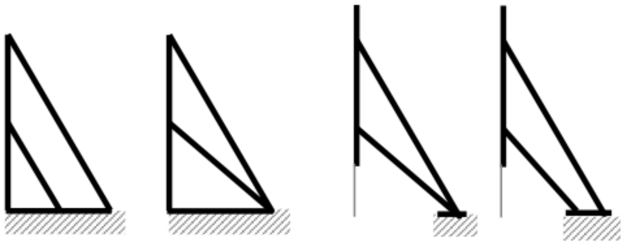


Fig. 3 _Props with a support base and converged or parallel beams and props with crutch based on a point or a supporting area

In case of wooden props, the nodes between the base, the upright and the strut are created by means of joining screws and metal staples. The contrast at the base, instead, depends on the nature of the ground surface or the road surface and it is secured by a configuration with coupled pickets or a configuration with contrasted dual beams.

In addition to the tubes and clamps systems or systems in wood, they can also utilize metal structural carpentry. These structures are prefabricated and modular, the elements of which are joined by bolting or welding, with the foundation in concrete plinths. The beams are arranged perpendicular to the wall and tightened using ribbed plates equipped with worm screws.

The schematics include the following steps: mounting and positioning the support surface to the wall, the predisposition of the ground anchorages and assembly of inclined elements.

Fig. 4 _Wooden retention shoring

The "counteracting shorings" are used when it is necessary to counteract the phenomena of tilting or bulging of the walls of buildings located at a distance less than twice the height of interstory.

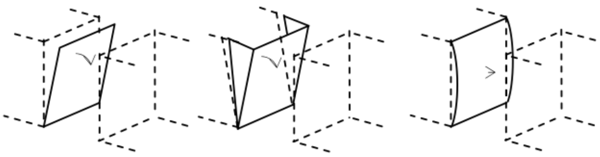


Fig. 5 _Kinematic mechanism of overturning or bulging that can be contrasted with counteracting shorings

In case of a seismic event, they run the risk of triggering the phenomena of pounding and generating cracks if the masonry is not able to withstand the thrust. To respond to this critical position, it is convenient to place counteracting props in correspondence to the transverse walls and to the horizontal elements of two buildings. Otherwise, in proximity to the building that has to be counteracted, it can be done with a scaffold that ensures the support. If the horizontal elements have different heights of the horizontal elements, it is necessary to use a vertical element that ensures the distribution of the forces. When the walls of the buildings placed at limited distance have an equal height, an equal contrast system is used; if they have a different height, a contrasting system of discharge is used. On the one hand, the counteracting props favour the distance of the road. On the other, they do not permit a rapid evacuation of the area in case of danger.
The implementation phase involves the construction of trellises for distribution, their connection with transoms,

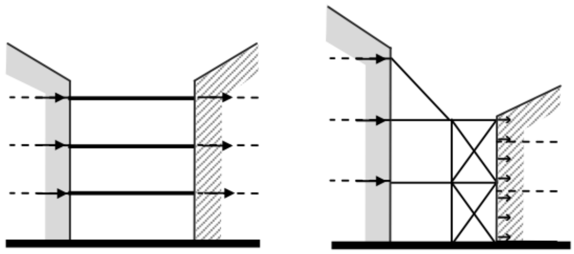


Fig. 6 _Configuration of safety system with horizontal element at the same height or at different height.

Fig. 7 _Counteracting shoring with tubes-clamps system

and completion with elements of contrast with braces.
The support shorings are intended to avoid the vertical translation of horizontal elements (floors and beams) in the following ways: to support parallel vertical elements (walls and columns) that have lost their bearing capacity, to avoid the fall of a heavy mass on an opening and to prevent the bulging of the masonry sides due to an opening.
The props are vertically arranged, and generate a transfer load onto the prop that is stressed in compression. Therefore, it is necessary that the mass subject to intervention is not able to guarantee the absorption of localized actions generated by the shore and that they use distribution elements of force, such as wooden boards.

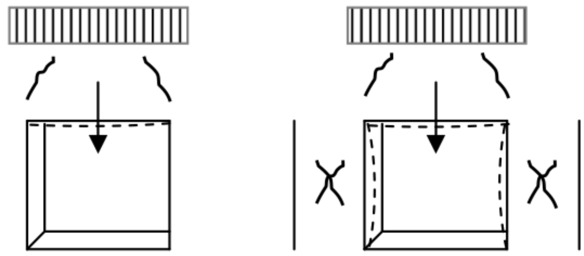


Fig. 8 _Kinematic mechanism of the fall of the above wall or side bulging side to counter

Concerning the safety work of the opening, the purpose is to support the vertical loads by transferring them to the bottom and to resist lateral deformation. To fulfil these tasks immediately upon construction, the safety system must be subjected to an action of compression. Thus, it is imperative *to define a state of tension similar to that existing before the collapse by stiffening elements of the opening*[5] by stiffening elements of the opening.
The construction scheme varies according to the height, width and thickness of an opening.
In examining the support of floors or balconies, the purpose of the provisional work is to discharge the load weighing on the element and counteract their translation, which lowers excessive inflection.
Through the creation of new lines of discharge or restoring the transfer of the load (while the carrier elements are still unharmed), the possible cracks are counteracted with the intrados at the middle or extrados at the top end.
The construction scheme varies depending on the structural length of the floor, on the height of interstory and on the transverse distance of props.

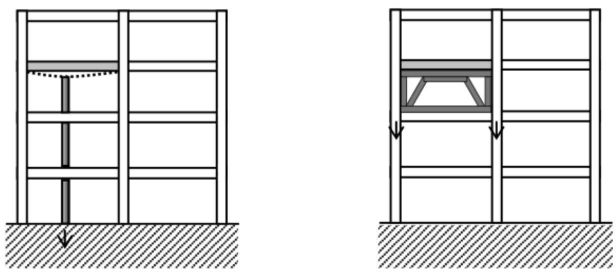


Fig. 9 _Creation of new lines of discharge or restoring the transfer of the load

Fig. 10 _Support shoring with props

Focusing on the crowning of arches and vaults, the purpose of the provisional work is to support the load weighing on the arc by discharging it to the ground and reduce stress on the piers. This method prevents breakage of the arch or vault.
The centring frame can be made in a closed or opened way, based on the need to maintain the passage.
The constructed scheme varies in function of the dimension, depending on the height of the arc or vault, the distance between the uprights, and the thickness of the wall. *A particularly critical issue to handle is the one connected to the fact that the supporting zone of the centring frame may suffer deformation or excessive sagging due to the new loads transmitted by the provisional work.*[6]
That critical issue can be resolved by checking the bearing capacity of the base before mounting the centring frame, possibly using elements of load distribution.
In addition to the systems with tube-joint or wood, they may also use metal telescopic props or iron props.

Fig. 11 _Centering with multidirectional system

Hoopings

The hooping has a containment function and serves to counteract effects of compression and/or shear, in order to prevent the phenomena of bulging or swelling. The larger the plan dimensions of the structure are the smaller the containment capacity of the hoop is.
This safety system is particularly effective for compact elements (columns, towers, bell towers, masonry buildings of small size), in which limiting the cross delay generates a state of tri-axial compression. This increases the ductility and the collapse load due to normal stresses.

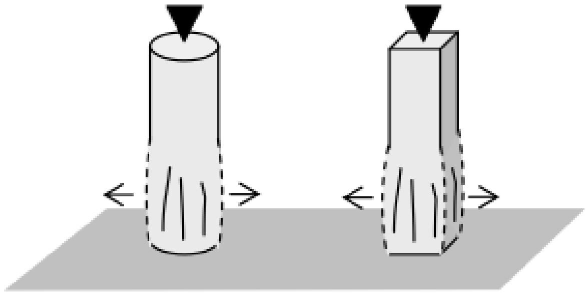


Fig. 12 _Kinematic mechanism of bulging and lateral expulsion that can be contrasted with hoop

Furthermore, the system is widely used in cases where it is impossible to gain inside access for safety modifications.
Depending on the area being safeguarded, the type of movement to counter and the geometric and constructive characteristics of the building, the hoop can be:

- total external: completely surrounding the building
- partial passing: it wraps a part of the building by passing through aligned side openings
- bound: anchoring to the side walls.

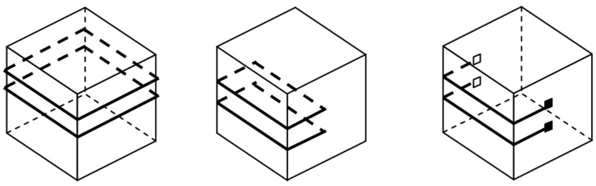


Fig. 13 _Total external, partial passing and bound hoop

Fig. 14 _Total hoop with mixed system

The hoopings are made by:

- bands in polyester: the stringing takes place by means of pawls with manual adjustment preparing of angles with rounded edges to eliminate the risk of abrasion of the fabric;
- tubes and clamps integrated with steel cables in strands: a structure formed by tubes and clamps is placed in contact with the compromised wall and is subsequently anchored to the building by means of steel cables in strands put in tension;
- metal profiles and steel cables: a structure formed by horizontal and vertical metal beams is placed in contact with the compromised wall and is subsequently anchored to the building by means of steel cables put in tension through of plates stuck in the wall;
- wood and steel cables: a structure formed by posts and wooden crosspieces is placed in contact with the compromised wall and subsequently anchored to the building by means steel cables put in tension through plates stuck in the wall.

Tie rods

The chains and anchors provide a box-like behaviour of building and have the purpose of counteracting the continuation of the reversal or bulging of one or more walls of the building due to a lack of clamping between the walls or between the walls and floors or due to the presence of horizontal elements pushing.

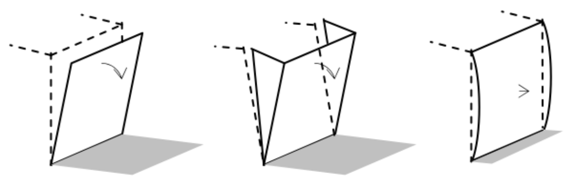


Fig. 15 _Kinematic mechanism of overturning or bulging that can be contrasted with tie rods

It applies a localized containment action distributed through the uprights and crosspieces in contrast with the wall being supported.
Therefore, these elements have the function of struts and allow the wall structure to repel the shot by bending stresses. The tie rods are brought into traction using key elements (plates or bars). It is applied in a perpendicular direction to the wall being guarded and when it is possible, in correspondence of the floors so that these act as resistant elements of contrast.
Depending on the area to guard, and the type of movement to counteract the geometrical and constructive characteristics of the building, the hoop may be:

- outer side: tie rods of opposing walls and passage of tie rods parallel to the transverse walls;
- inner passing: tie rods of opposing walls and passage of the tie rods inside the building;
- side bound: tie rods of a wall by means of crossbars anchored to the side walls of the building.

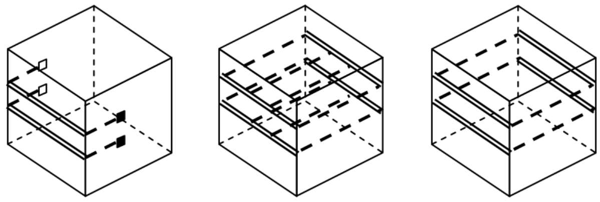


Fig. 16 _Outer side, inner passing and side bound tie rods

Fig. 17 _Inner passing tie rods

These safety systems are made by steel beams and tie rods, tubes- clamps and tie rods, wooden elements and tie rods and modular metal prefabricated structures and tie-rods. The structure is contrasted to the wall to be supported by post-tensioned bars made in ordinary steel or high elastic bars limit bounded to the ends by and plates and stakes.

Jacketings

The jacketings have the purpose of counteracting the transverse deformations or bulging of the wall panels due to excessive vertical loads. The element is "jacked" through formworks or wooden structures connected by tie rods passing in holes in the masonry. The brickwork must not be particularly rough in that it must be resistant to the vibrations due to the predisposition of the holes.
The implemented scheme provides for the resulting stages: the perforation of the walls insert steel bars, the mounting and positioning of a structure for distribution of loads on both faces of the wall, the placements of pairs of wooden elements on both walls, the threading of the contrast plates, the stringing of the bars and terminal tightening.

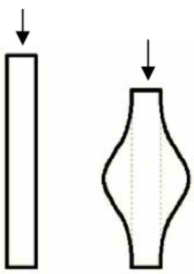


Fig. 18 _Kinematic mechanism transverse deformation or bulging that can be contrasted with jacketing

Fig. 19 _Cover with steel structural profiles

Coverings

The coverings are designed to protect buildings from atmospheric agents that have suffered the partial collapse of the original hedge. They are constituted by a steel supporting structure, tubes-clamps or wooden elements, often independent of the building, which supports light closure elements in sheet metal, sheeting or plastic.
The choice of the type of structure and materials is strongly influenced by the conditions of the buildings and of the duration of the intervention.

4.3 _ Definition and analysis of the safety systems

The definition and analysis of the provisional safety system allows for the identification of the constructive characteristics, the assembly time, the durability of the components and the residual performance, with the aim of optimizing their reuse.
The use of specific provisional systems in safety operations is dictated by the geometric and constructive characteristics of the building, the function to which the safety has to perform (replacement, cautionary, and protective), the type and severity of the damage the building has suffered, phenomena to counteract (bulging and overturning), from the constraints/restrictions dictated by the context since the time available for the intervention. In addition, they have imposed the use of systems already widely available on the market because of the extraordinary need to act in a short time under the aim not only to protect the safety of workers and restore viability, but also to safeguard the historical-artistic value and limit further damage caused by aftershocks.
Consider, for example, the use of steel profiles mainly of the UPN type. This choice depends not only on the type of profile that, thanks to its open shape, allows easy operations of welding and bolting, but depends above all by the availability of the steelworks that, post- earthquake, were able to respond to the large demand for steel elements through this specific profile. Currently, the homogeneity of the used components, although not programmed, appears as a resource as it simplifies any reuse operations, which narrows the scope of possible interventions. Therefore, multiple factors have influenced the use of specific safety systems, herein described and analysed individually.
It must be emphasised that the use of a system does not exclude the temporary use of another system on the same building.
Sometimes we proceed to the integration of two or more systems that work together to perform the same function other time, although the intervention guarantees global security of the same building, different systems work independently.

Steel systems

For safety systems that have been used in the majority of systems that consist of steel elements, the dimensional and structural characteristics of this material, the possibility of reversible connections (bolting, interlocking) and the rapidity of assembly are exploited.
The systems can be divided into:

- modular systems: they perform a certain formal and constructive logic, both in reference to components that connect; they are constituted by prefabricated modular elements, their conformation may undergo variations limited in the range of possibilities provided by the system, can be, therefore, closed systems; belong to this type:
  - tubes-clamps system
  - multidirectional system;
- combinable modular systems: they consist of prefabricated elements and can be assembled according to different conformations that give rise to many possibilities; they can be defined, therefore, as "open systems";
- systems with steel cables: they are constituted by steel cables, which contrast and tighten elements. The components remain unchanged by type but undergo dimensional changes. The distributed elements of the load are often used in conjunction. In this sense, the modular systems and steel structures can be integrated into the system with steel cables, which fulfil the function of distributing the loads with the view to perform operations of putting on safety through wrapping and hoops. With the same purpose, the warping of distribution can be formed also with steel elements mixed with wooden elements and more rarely, only of wood.

Fig. 20 _Integration of systems with different functions

Tubes-clamps system (Innocenti tubes system)

The system consists of two main elements: the tubes and the clamps that connect them. They are made with steel, painted and/or with hot dip galvanized or electrolytic.
The type of steel used for the tubes is predominantly S253JR, while for clamps S355MC and S355JR.
The components[7] that constitute the system are:

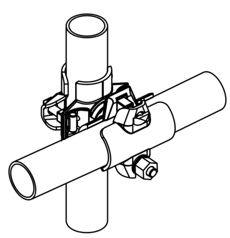
Tube

diameter ext.: 48,30 mm
thickness: 3,20 mm

length mm	weight (painted) daN
750	1,65
1000	2,48
1200	3,30
1500	3,96
1800	4,95
2000	5,94
2500	6,60
2750	8,25
3000	9,08
3600	9,90
4000	11,88
4500	13,20
5000	14,85
5400	16,50
6000	17,82

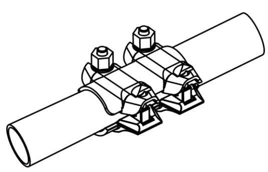
Right angle clamp: it allows connections to 90° with capacity up to 1000 Kg

weight: 1,35 daN
dimensioni: 130x80 mm



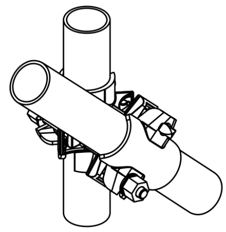
Traction clamp: tube connection that guarantees a traction resistance of 4500 Kg

weight: 1,80 daN
dimensions: 130x80 mm



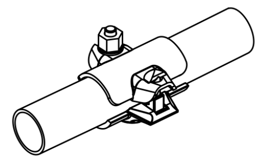
Swivel clamp: it allows connection according to variable angles of 180° in reference to two planes, with capacity up to 700 kg

weight: 2,40 daN
dimensions: 130x80 mm



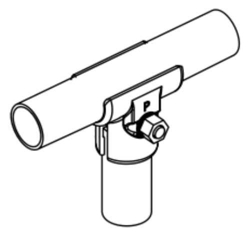
Sealing clamp: it strengthens the union of the tubes along the same line

weight: 0,70 daN
dimensions: 130x80 mm



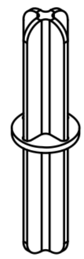
Terminal clamp: final part of the system

weight: 1 daN
dimensions: 150x80mm



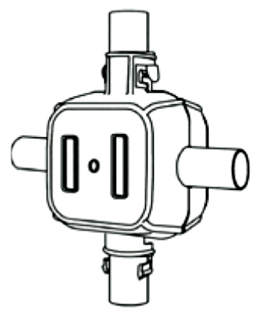
Cross pin: it allows the connection head to head of the tubes

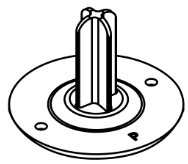
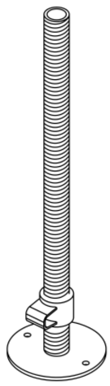
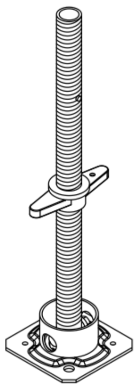
weight: 0,60 daN
dimensions: 200x40 mm

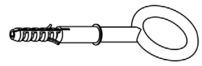


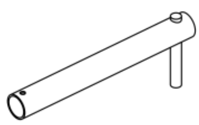
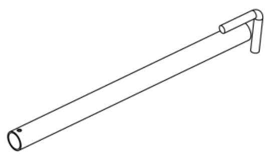
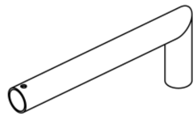
Clamp cover in polypropylene: covering elements of the node

weight: 0,1 daN
dimensions: 150x150 mm



Base plate: element used for anchoring the tube to the ground		
fixed height weight 0,88 daN dimensions 145 x 112 mm		
adjustable height		
dimensions mm	weight daN	
480 mm x ϕ 145 mm	2,40	
715 mm x ϕ 145 mm	3,00	
1000 mm x ϕ 145 mm	4,00	
adjustable and inclinable height weight: 3,5 daN dimensions: 600 mm		

Dowel: it allows anchoring to wall	
weight: 0,50 daN dimensions: ϕ 50 mm	

Anchoring: it allows anchoring to the dowel	
with pin weight: 1,7 daN dimensions: 300 mm	
with hook weight: 2,6 daN dimensions: 600 mm	
with tube weight: 1,9 daN dimensions: 300 mm	

The standard pattern of mounting for construction/maintenance works, involves a variable interest from 1800 mm to 2500 mm and a width of 1100 or 1200 mm. The maximum permissible load is 300 daN/sqm.
The assembly is completed from the bottom up by placing first the base plates on the ground level, then connecting them with the currents and further by mounting the first scaffold. Using the latter, it is possible to place the uprights and the upper scaffolding. The disassembly takes place in reverse. The clamps are first placed on the tube and tightened through n.4 bolts, headnuts and washers.
The tightening of the bolts must be realized as a torque movement not exceeding to 600 kg cm, controlled through wrench keys. The system has a high reversibility and a high flexibility, since, by separating the clamp from the tube, it is possible cut the tube according to the necessary dimensions without compromising the ability of connection and it is possible to vary the height of positioning of the clamps along the tube. This allows their use in any situation such as in the presence of arches and vaults or of a well-articulated planimetric conformation. The high weight, in comparison to other systems present on the market, has a negative impact on the timing of assembly/dismantling (and consequently on the costs); therefore, it requires specialized workers. The time of installation of a standard system (1.10m x 1.80m) is equal to 20 min/sqm, considering the use of 1 skilled worker, 1 qualified worker and 1 common worker. The time of disassembly is equal to the time of installation, considering a reduction factor equal to 0,9, namely, it is equal to 18min/sqm.

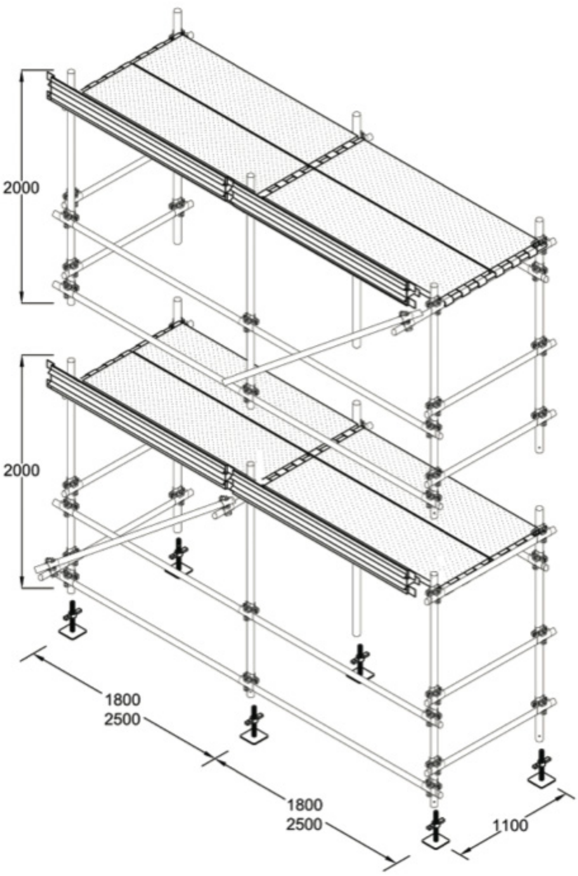


Fig. 21 _Standard scheme to assembly

Multidirectional system (multicom system)
The system consists of three main elements: tubular uprights with jack rosette, tubular beams and tubular diagonal elements. The types of steel used are mainly S235JR, S355JR and S355MC, with galvanized hot-dip. The upright is equipped with a jack/rosette welding every 50 cm, consisting of an octagonal plate with 8 shaped punctures to receive the connecting devices to quick coupling located at the ends of the beams and diagonals. The butt joint is inserted into the perforated plate and lowers the wedge sliding it into the slot of the perforated plate, which is then fixed with a hammer blow.
A rivet placed at the far end of the wedge prevents the removal of the wedge. Otherwise, the connection between uprights takes place with interlocking by insertion.

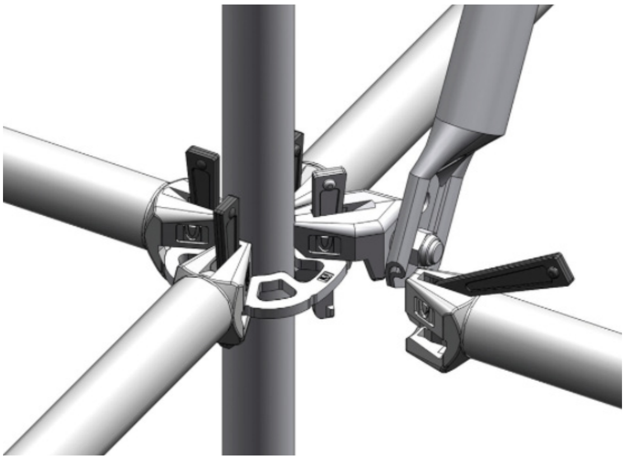


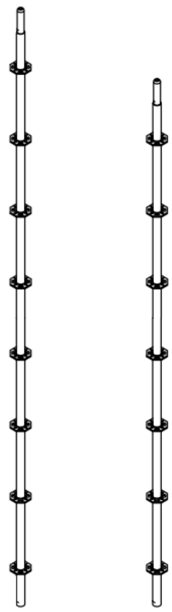
Fig. 22 _Detail of the interlocking by inserting

The components[8] that constitute the system are:

Upright with pin: vertical element with integrated joint

diameter ext.: 48,30 mm
thickness: 3,20 mm

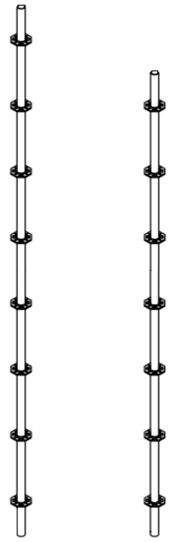
length mm	weight daN
250	1,50
500	2,70
1000	5,40
1500	7,70
2000	9,80
2500	12,00
3000	14,30
4000	18,70



Upright without pin: vertical element with integrated joint

diameter ext.: 48,30 mm
thickness: 3,20 mm

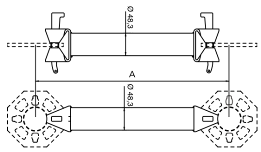
length mm	weight daN
250	1,30
500	2,00
1000	4,60
1500	6,90
2000	9,00
2500	11,20
3000	13,50
4000	17,90

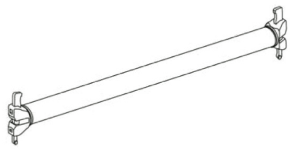


Current: horizontal element

diameter ext.: 48,30 mm
thickness: 3,20 mm

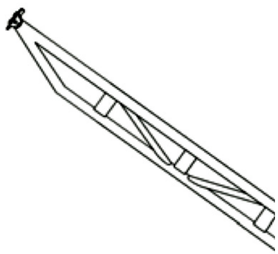
length mm	weight daN
413	1,90
750	3,20
1000	4,30
1050	4,40
1130	4,60
1500	6,00
1800	7,10
2000	7,80
2500	9,60
3000	11,40



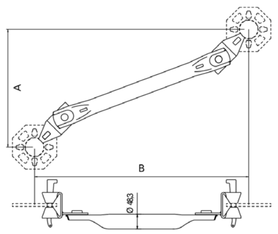


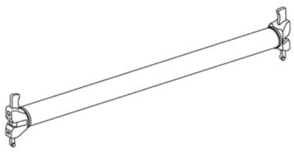
Reinforced truss: for horizontal union

length mm	weight daN
1500	9,50
1800	12,40
2000	13,70
2500	16,80
3000	19,70

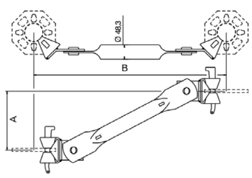


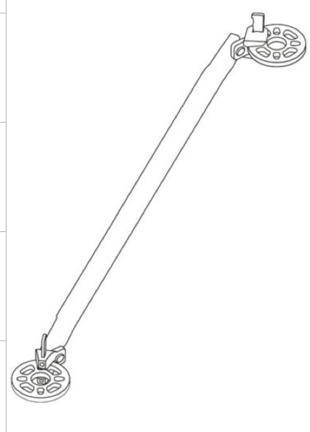
Diagonal of plan	
diameter ext.: 48,30 mm thickness: 3,20 mm	
width x length mm	weight daN
1000x1000	5,50
1000x2000	8,30
1500x1500	8,40
1500x2500	10,90
1800x1800	9,80
2000x2000	11,50
2000x2500	13,20
2500x2500	14,60
2500x3000	15,00



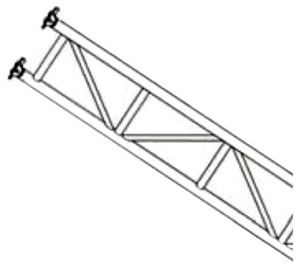


Diagonal of prospectus	
diameter ext.: 48,30 mm thickness: 3,20 mm	
height x length mm	weight daN
2000 (1500- 1000- 500) x750	8,60 (6,90- 5,30- 3,90)
2000 (1500- 1000- 500) x1000	8,90 (7,20- 5,80- 4,60)
2000 (1500- 1000- 500) x1050	9,00 (7,40- 5,90- 4,80)
2000 (1500- 1000- 500) x1130	9,10 (7,50- 6,10- 5,10)
2000 (1500- 1000- 500) x1500	9,70 (8,30- 7,10- 6,30)
2000 (1500- 1000- 500) x1800	10,40 (9,10- 8,00- 7,30)
2000 (1500- 1000- 500) x2000	10,80 (9,60- 8,60- 8,00)
2000 (1500- 1000- 500) x2500	12,20 (11,10- 10,20- 9,70)
2000 (1500- 1000- 500) x3000	13,50 (12,60- 11,9-11,40)

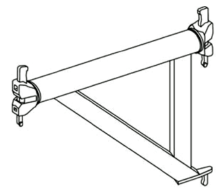




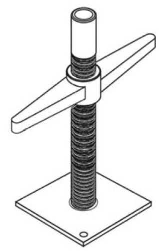
Truss with latching wedge: for horizontal union	
height : 500 mm	
length mm	weight daN
2000	36,00
2500	39,00
3000	46,00
4000	51,90
5000	63,10
6000	71,80

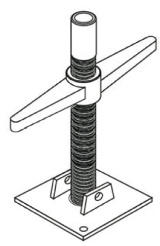


Shelf: for reinforcement	
length mm	weight daN
400	3,40
750	6,00

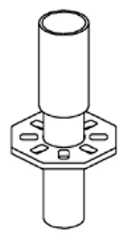


Base plate: element for supporting the upright	
adjustable height	
dimensions mm	weight daN
350 (max 250)	4,00
500 (max 350)	5,50
800 (max 550)	7,00
1000 (max 700)	8,50
adjustable and inclinable height	
dimensions mm	weight daN
500 (max 350)	2,80
1000 (max 700)	5,10



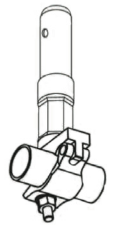


Starting element: connected with the base plate
diameter ext.: 48,30 mm thickness: 3,20 mm height: 23,5 cm weight: 1,60 daN



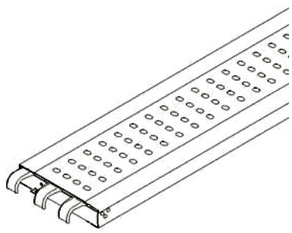
Starting intermediate element: for the phase displacement with respect to the main lines of the uprights

weight: 2,30 daN



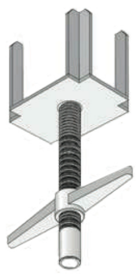
Galvanized table: decking supported on currents

width x length mm	weight daN
309 (330-360) x 750	5,67 (__-18,10)
309 (330-360) x 1050	7,15 (11,16-18,10)
309 (330-360) x 1500	9,36 (9,64-18,10)
309 (330-360) x 1800	11,31 (11,1-18,10)
309 (330-360) x 2000	12,35 (12,2-18,10)
309 (330-360) x 2500	14,94 (15,4-18,10)
309 (330-360) x 3000	18,34 (18,9-18,10)



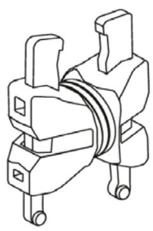
Cross head

height: 500 mm (max 350 mm)
weight: 5,00 daN



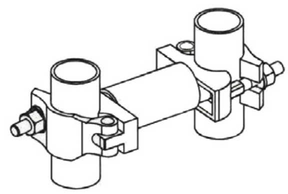
Head joint: between horizontal elements on the same line

weight: 2,80 daN



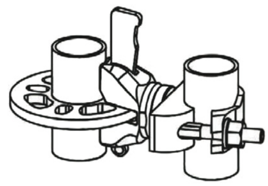
Parallel joint: at variable height between vertical elements

weight: 2,10 daN



Obliged parallel joint: at obliged height with step from 50 cm between vertical elements

weight: 1,50 daN

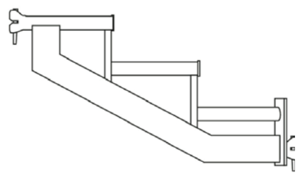


Ramp aluminium ladder

length: 2500 mm
(related to the distance between the uprights)
height: 2000 mm
width: 612 mm
weight: 26,00 daN

Side of the ramp

height x width mm	weight daN
500 x 1000	14,00
1000 x 2000	27,00
1500 x 3000	32,00



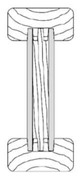
Mobile hinged rosette: for hooking variable currents along the upright

dimensions: 120x120 mm
weight: 1,0 daN

In their traditional use for construction/maintenance, the standard spans of mounting are 1800x1050 mm.
The elevation is variable with the step of 500 mm and is generally 2000 mm. The maximum permissible load is 300 N/sqm, evenly distributed.
The assembly begins with the positioning of the bases on which are mounted the elements of departure, joined by means of currents. Thereafter, they are inserted into the uprights and they then proceed with the assembly first of the transom and then they lean on galvanized boards.
The system is stiffened by diagonal elements.
Through the connection elements of cross head (or fork), the multidirectional system is used with a shoring support system by building towers that support a warping of beams. Depending on the size of the span of the tower, the number of stiffeners, the height of the supported plan, the distance of the towers and the type of the transoms (section and material), the system can withstand different loads. The following are typically used:

From a structural point of view, the engagement between uprights and the horizontal element is the weaker point, but the type of connection makes assembly possible without a specialized workforce.
The cost of the component within the system is highest compared with the "innocenti tubes" system.
The multi-com system has a high reversibility, but the presence of joints incorporated on the uprights with predetermined pitch makes the system inflexible because it is not possible to cut the tubes according to the needs or make connections at angles other than 90°. On the contrary, the presence of incorporated joints and the type of interlocking connections speed up the operation of assembly and disassembly. In fact, the time for assembling a system in mesh standard (1.10 m x1.80 m), considering the use of 1 skilled worker, 1 qualified worker and 1 common worker is equal to 15 min/sqm. The time for disassembly is equal to the time of assembly, considering a factor of reduction equal to 0.9, namely equal to 13.5 min/sqm.

- Wooden beam IPE
  Height: 20 cm, Peso: 5 Kg/m
  Elastic module: 1030 kN/cm2
  Moment of inertia: 4383 cm4
  Shear stress amm.: 11,0 kN
  Bending moment amm.: 5 kNm



- Steel beam S355LL with double C
  Height: 20 cm
  Width:15 c.
  Weight: 22 Kg/m
  Elastic module: 20600 kN/cm2
  Moment of inertia: 1237 cm4
  Resistance module: 123,0 cm3

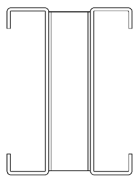


Fig. 24 _Details of support shoring, L'Aquila, Corso Vittorio Emanuele, april 2013

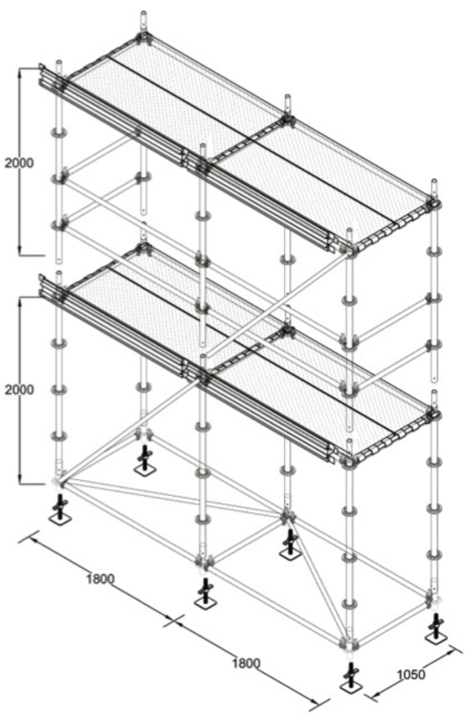


Fig. 23 _Standard scheme to assembly

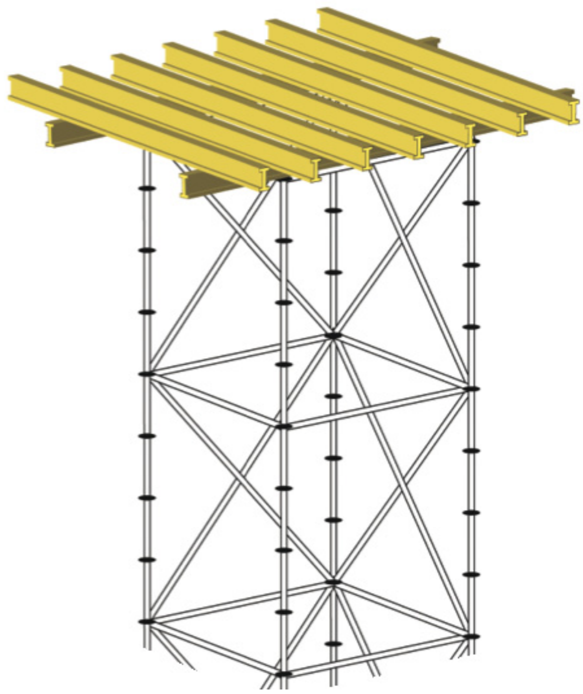


Fig. 25 _Scheme of tower of shoring

Combinable modular systems

They are constituted by steel profiles, generally perforated, which are joined to form a spatial structure with different conformations by bolting. In addition, any joint elements are perforated in order to simplify the union.
In the case of the realization of coverages, they are integrated with corrugated plastic material or corrugated sheeting. With respect to the function for which they perform, the characteristics of the building and to the constraints of the context, they can be combined or separated from the building.
Generally, this type of structure needs a suitable ballast or ground anchor.
The system modularity and the use of perforated profiles on all sides allows for the production of complex structures with different shapes and sizes, so the system has very high flexibility. Bolting also allows high reversibility, ensuring the perfect integrity of all components after dismantling. Rarely, the structures are made of welded steel profiles type UPN or HEA to form metal structures thrust or coverage. In this case, the system is flexible, but poorly reversible.
It is difficult to estimate the average time of assembly/disassembly due to multiple conformations that are achievable. Whereas the use of 1 skilled worker, 1 qualified work and 1 common worker, the time in case of complex conformations is equal to 60 min/sqm and in case of simple conformations is equal to 30 min/sqm.

Fig. 26 _Metallic carpentry with welded profiles

Systems with steel cables

The systems with steel cables consist of the following main elements:

- tie: can be made with a drawn, smooth or threaded bar, depending on the requirements; in case of emergency, to facilitate the supplying they often use drawn bars in steel and strengthen with improved adherence (generally used for the reinforced concrete) providing to weld on the terminal part of a threaded bar, with overlapping welded at least 20 cm; generally, they present a variable diameter in the range between ϕ12 and ϕ24;
- end element: it is a retaining element which can be constituted by a bollard of length including between 80 and 120 cm, positioned according to an angle of 45° or by ribbed plates generally circular or square shaped with a diameter or side between 30 and 50 cm; alternatively, they can also be used in nut locking systems for metal shuttering used in construction; this enables an easy mechanical mounting;
- wing nut/tensioning joint: it is the element that is used for tightening through wrenches in the case of rods and through hydraulic jacks in the case of strands; the joint can be positioned at the far end of the tie rod or in an intermediate position, acting as a connection between the two arms of the tie rod; for terminal joints, they use nut and key elements applied on the key elements through a threaded lug; otherwise, for joints of intermediate tensioning, they use a tensioning sleeve having at its ends hooking systems to an eye, fork or rod;
- elements to distribute loads: they are present only when it is necessary to contain the entire wall and maximize the area that is affected by the tie rod by spreading the effort evenly; they are constituted by a grid of uprights and crossbeams; the type of structure and allocation may be made from:
    - uprights with UPN single profiles arranged with the web in adherence to the building made integral through welded or bolted shelves with horizontal UPN profiles coupled on the side of the flange, on which is positioned the retention element; sometimes there are additional outer uprights constituted by single UPN profiles anchored by double plates bolted to the crossbeams;
    - uprights with UPN profiles coupled on the side of the web and placed with the flanges in adherence to the building, made integral through welded or bolted shelves with horizontal UPN profiles coupled on the side of the web; the retainer elements sometimes present bracing systems with "innocenti tubes";

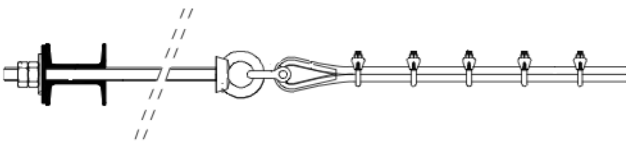


Fig. 27_Bolted plate resting on UPN coupled beams

Fig. 28 _Uprights and crossbeam with UPN profiles coupled on the site of web plate, steel shelf

Fig. 29_Uprights single UPN profiles, crossbeams with UPN coupled profiles, steel shelf, single UPN beams

Fig. 30 _ Uprights and cross beams with UPN profiles coupled on the side of the web plate

Fig. 31 _Uprights and cross beams with UPN profiles coupled on the side of the web plate, steel shelf, upwinds with tubes-clamps system

  - crossbeams with UPN profiles coupled on the side of the web and placed with flanges in adherence to the building, made integral through welded or bolted shelves with vertical UPN profiles coupled on the side of the web, the retainer elements are placed both on uprights that on crossbeams;
- uprights with steel IPE profiles, placed with one of the flange in adherence to the building and the other welded with the web of beams by single UPN profiles, on which is placed the retainer element;
- crossbeams with UPN profiles coupled on the side of the web and placed with the flange in adherence to the building, on which is placed the retainer element;
- crossbeams with HEA single profiles placed with the flange in adherence to the building, made integral through welding with uprights with coupled HEA profiles, the retain element is positioned on the uprights;
- uprights with coupled steel HEA profiles, placed with one of the flange in adherence to the building and the other welding with the flanges of the transoms constituted by HE coupled beams, the retainer element is placed on the transoms and on the uprights;
- uprights with single HEA profiles, placed with one of the flange in adherence to the building and the other welding on crossbeams constituted by coupled UPN profiles on which there is the retainer element;
- coupled HEA uprights, placed on with one of the flange in adherence to the building, with retainer elements;
- welding single UPN uprights and crossbeams, with retainer elements on the beams, placed with the web parallel to the front of the building;
- single UPN uprights with retainer elements on the web of the profiles.

It should be noted, however, that the wrapping of distribution may also be constituted by integrating elements of wood or in steel. In particular:

- uprights in wood with shelves in wood or in steel supporting crossbeams in UPN coupled profiles, or reticular truss on which is placed to contrast the retainer element;
- uprights in wood coupled with retainer elements, with steel shelves supporting crossbeams in UPN profiles coupled also them with retainer elements;
- uprights and crossbeams in wood, with coupled elements and connection shelves in steel;
- uprights with wood coupled elements with steel shelves and beams with HEA profiles, placed with one of the flange in adherence to the uprights, the retainer element is placed drilling the wings;
- single upright in wood joined by nailing with beams with double elements in wood.

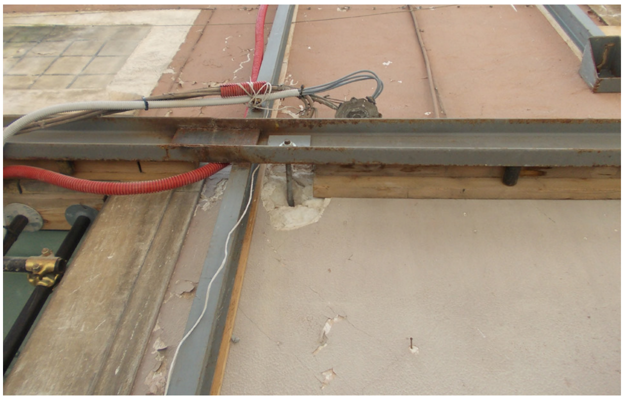


Fig. 32 _Uprights IPE profiles,
crossbeams single UPN profiles

Fig. 33 _Crossbeams UPN coupled profiles

Fig. 34 _Crossbeams single HE profiles, uprights HEA coupled profiles

Fig. 35 _Uprights and crossbeams HEA coupled profiles

Fig. 36 _Uprights HE, crossbeams couples UPN profiles

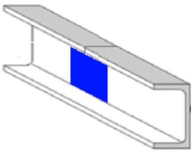
Fig. 37 _Uprights HEA coupled profiles

Fig. 38 _Uprights and crossbeams single welded UPN profiles

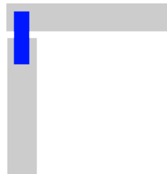
Fig. 39 _Uprights single UPN profiles

Between the uprights or main beams (as described above) and the wall, wooden planks are placed to ensure the coplanarity and perfect adherence with the vertical plane. This placing overcomes the uneven share derived from frames, window, sills or other objects.
Depending on the present damage and the type of failure to counteract, the aim is to further maximize the area of action of the tie rod.
The planks of wood can also be placed perpendicular to the elements closer to the facade. Depending on the needs, further components can be used: spacing elements in case of using coupled steel profiles, mainly consisting of steel tubulars; steel brackets of anchor, both for the connection between uprights and beams, that for definition of the corner point in the event of curvature of the tie rod, plates, screws and bolts that for the connection of the steel and the wood and that for the connection of the tie rod to the wall.
The dimensioning of the elements takes place according to the type of failure to counteract (through tie rods or hoopings), to the constructive characteristics of the building and to the type of the damages, to the length and height of the wall to guard, to the passage of the rods and to the wheelbase of uprights and beams.
The constructive elements always maintain dimensional coordination. For example, depending on the rod, it is possible to identify the size of other elements.
For what concerns the distribution elements, they have been used HEA profiles (from HEA 140 to HEA 260), UPN profiles (from UPN 160 to UPN 200), wood elements (section from 10x10 to 20x20 cm) and wood timber (2.5x12 and 5x20 cm).

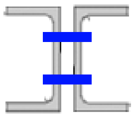
The reversibility of the system depends on the type of union that was utilized. Steel cable exclusive systems and the components closely related to it (clamp, turnbuckle, shackle, etc.), presents high reversibility as there are unions for bolting. Otherwise, for this, which concerns the distribution elements, when the profiles/elements are joined by bolted plates through bolts or dowels, the system presents a high reversibility. However, it contrarily presents a low reversibility when the profiles are welded in place.
For a deeper analysis of the reversibility of the distribution system it is necessary to evaluate the following connections:



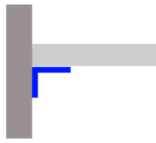
Union of the beams horizontally or uprights vertically



Union of the corner of the beams



Union of the coupled profiles



Union between uprights and beams

The assessment must be carried out according to the following scale of reversibility:

welding nailing screwing bolting

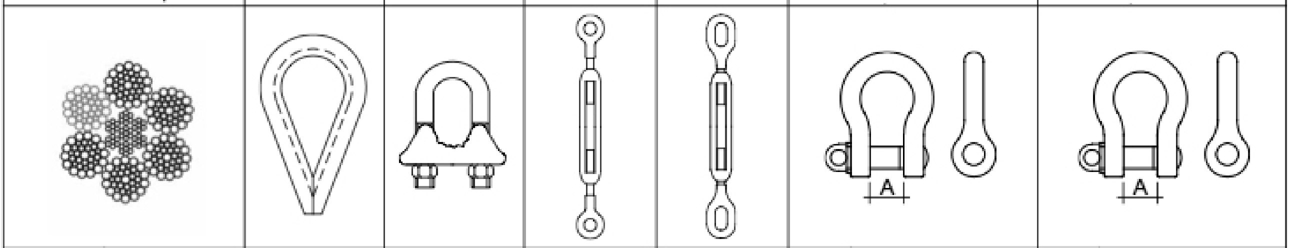
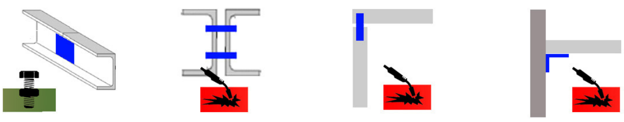
Cavo di acciaio Modulo di elasticità: 11000 daN/mmq		Redancia zincata	Morsetto a cavallotto	Tenditore tipo O-O	Tenditore tipo II B UNI 2020	Grillo omega per tenditore tipo O-O		Grillo omega per tenditore tipo II - B	
									
Diametro (mm)	Portata (t) Coef. sicurezza: 2,5	Dimensioni	Marcatura	Filettatura ISO	Filettatura ISO	A (mm)	WLL codice stampigliato sull'elemento	A (mm)	WLL codice stampigliato sull'elemento
ϕ 12	3.52	12 A18	marchiati 13	M22	A27	22	2.00T o 2 T	26	3.25T o 3 1/4T
ϕ 14	4.78	16 A23.5	marchiati 14	M24	A30	26	3.25T o 3 1/4T	31	4.75T o 4 3/4T
ϕ 16	6.24	16 A23.5	marchiati 16	M27	A33	26	3.25T o 3 1/4T	31	4.75T o 4 3/4T
ϕ 18	7.92	20 A29.5	marchiati 18	M33	A36	31	4.75T o 4 3/4T	36	6.50T o 6 1/2T
ϕ 20	9.76	20 A29.5	marchiati 19	M36	A39	36	6.50T o 6 1/2T	36	6.50T o 6 1/2T
ϕ 22	11.78	22 A32	marchiati 22	M39	A45	36	6.50T o 6 1/2T	43	8.50T o 8 1/2T
ϕ 24	14.02	24 A35	marchiati 26	-	A52	-	-	43	8.50T o 8 1/2T

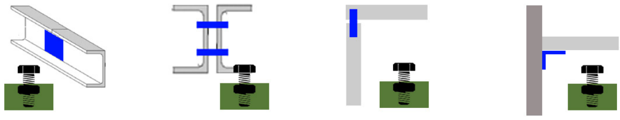
Fig. 40 _The table provides a schematization of the dimensional coordination of the components in depending on the diameter of the steel cable

It proposes the comparison between 3 safety systems that use steel cables with the aim to highlight the incidence of the type of connection on the reversibility. The chosen examples present very different levels of reversibility, which will affect not just the time and the cost of dismantling, but also the integrity of the components.
In the first case, the profiles are coupled by welding with a step of about 1 ml; therefore, during disassembly they will have to cut transversely. The beams will maintain the coupled conformation and the node between uprights and beams and the corner point will remain in solidarity. Therefore, the product of disassembly will consist of profiles of reduced size (up to 2 metres) coupled together and by node and angle elements, greatly limit the possibility of reuse.
In the second and third case, instead, thanks to the reuse of connections for bolting, after the disassembly, intact components that maintain their size and their original and geometrical conformation will be available, which can be easily reused.

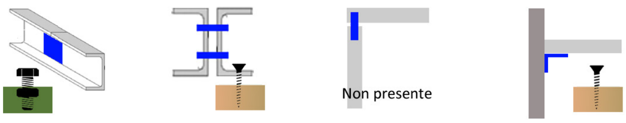
SYSTEM 1



SYSTEM 2



SYSTEM 3



The time for disassembly undergoes variations depending on the type of distribution and connection elements and is included in ranges between 40 and 50 min/sqm, considering the use of 1 skilled worker, 1 qualified worker and 1 common worker.
The time for disassembly is equal to the time of assembly. It considers a reduction factor equal to 0.9, which is included in the range between 45 and 35 min/sqm.

Fig. 41 _Hooping with polyester bands

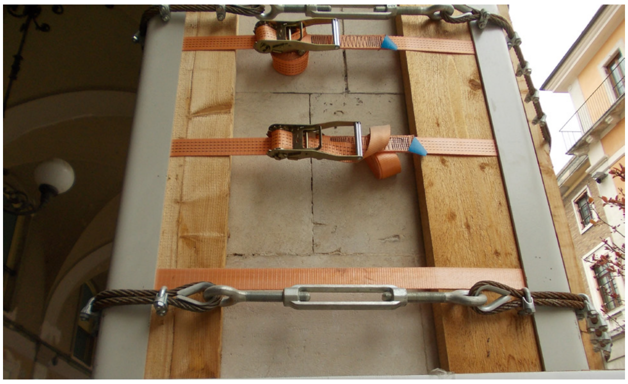


Fig. 42 _Hooking of the hoop

Fig. 43 _Hooping of a building with polyester bands

Polyester bands

The polyester bands are usable to make ligatures rings in the case of very compact elements (as columns or portions of building). The step of the bands varies depending on the damage and the geometry of the section of the element that have to be hooped. The step on a circular element is greater than the step on a rectangular element that has the same area.
While in the first case, the bands produce uniform pressure on the whole lateral surface, in the second case, they produce concentrated forces on the edges. Generally, the step varies between 13 cm and 81 cm in the case of the circular section and between 15 cm and 51 cm in the case of a rectangular section.
The bands, having a height of 50 mm or 70 mm, are positioned and subsequently induce and maintain a pulling load by means of ratchets and manual adjustment. The bands are placed on steel elements (flat or angular) with the task of reducing damage and are protected with paints containing antioxidants and of a light colour to decrease absorption of solar radiation. These are arranged in transversal position, which, in turn, are positioned on wooden boards with a minimum thickness of 2.5 cm in order to compensate for the irregularities of the contact surface.

Phase 1: insertion of the tape from the bottom upwards
Phase 2: recovery of the excess tape
Phase 3: tensioning of the tape through lever

Generally, the bands with a minimum height of 75 mm present an exercise load equal to 10,000 kg and a breaking load equal to 20,000 kg. The bands with a height of 50 mm present, an exercise load equal to 5000 kg and a breaking load equal to 10,000 kg.
The ratchets are steel elements ranging in size depending on the width of the polyester band.
For bands having a height of 50 mm, the ratchet has dimension of 78 x 325 x 105 mm[9].
The flexibility of the system is conditioned by not only the length and height of the bands, but on the type of configuration. In fact, wanting reuse the same bands with a configuration different from that ring, they should undergo major changes in the sewing of small loops for the preparation of hooks or delta brackets.
The system is highly reversible, since the ratchet through a simple manual operation can be opened freeing the rope.
Considering the use of 1 skilled worker, 1 qualified worker, and 1 common worker, for bands with length less than 5 metres, the time for disassembly is equal to 40 min/cad.
For bands with length between 5 metres and 10 metres, the time of assembly is equal to 48 min/cad.
Bands with length exceeding 10 metres, the time of assembly is equal to 55 min/ca. Respectively, the time for disassembly is equal to 36min/cad and 50 min/cad.

Systems in wood

As previously described, wooden boards, primarily of section 2.5 x 12 cm and 5 x 20 cm, are used for the distribution of loads in combination with the steel systems.
The wooden boards are fixed with the reference plane (wall or floor) thanks to the pressure exerted by other components of steel systems. They are then connected for adherence, which ensures a high reversibility of the system in a short time. The dismantling of steel components causes the simultaneous uncoupling of the timber from the reference plane. Safety elements comprised entirely of wood are constituted by elements of variable sections dimensioned in function of the thickness of the wall and of the warping and are united through dry connections to form structures with different conformations: retention, counteracting, support shoring and centrings of vaults and arches. Generally, for the uprights and beams, elements with a square section are used, while the for the ground attachment and for the upwind diagonals, the elements with a rectangular section are utilized.
They are connected by means of screws, nails or staples, in coordination with dimensional wooden elements. Wooden elements have been used with variable sections in shape and in size, but the elements mainly used are described below:

Element	Screw	Nail	Pin
Morale 8x8 cm	ϕ 6x160	150	---
Morale 10x10 cm	ϕ 6x160	150	---
Trave 13x13 cm	ϕ 10x150	---	ϕ 16
Trave 15x15 cm	ϕ 12x180	---	ϕ 16
Trave 18x18 cm	ϕ 12x200	---	ϕ 16
Trave 20x20 cm	ϕ 12x200	---	ϕ 16
Tavola 2,5x12 cm	ϕ 5x100	80	---
Tavola 5x20 cm	ϕ 5x100	100	---

The sizing of the clips or staples is also strongly affected by the angle of inclination.
Therefore, it is not possible to outline it. They have standardized variable dimensions between 200 and 500 mm with a variable depth of inflection.
The wood connections dry with a medium-high level of reversibility, variable in the following order (from least to most reversible): stapling, nailing, screwing and pinning.
The wooden systems have at the time of their construction good flexibilityas the elements present on the market of variable dimension between 2 m and 5 m, can be cut with extreme ease and adapted to multiple needs.
Otherwise, once used, their flexibility is reduced, since, assuming a new use, we have available elements with smaller dimensions than that original commercial.
Therefore, it reduces the number of configurations and conceivable uses.
Concerning the reuse of connection elements, the screws cannot be reused due to the torque applied and is impressed and in a similar way to nails and staples due to the folds that undergo in their extraction from wood. Otherwise, the pins can be reused if they do not present forms of degradation (such as rust).
Considering the use of 1 skilled worker, 1 qualified worker, and 1 common worker, the time for the assembly for more complex work is about 5 h/m of materials and for less complex work, 3h/m of materials.

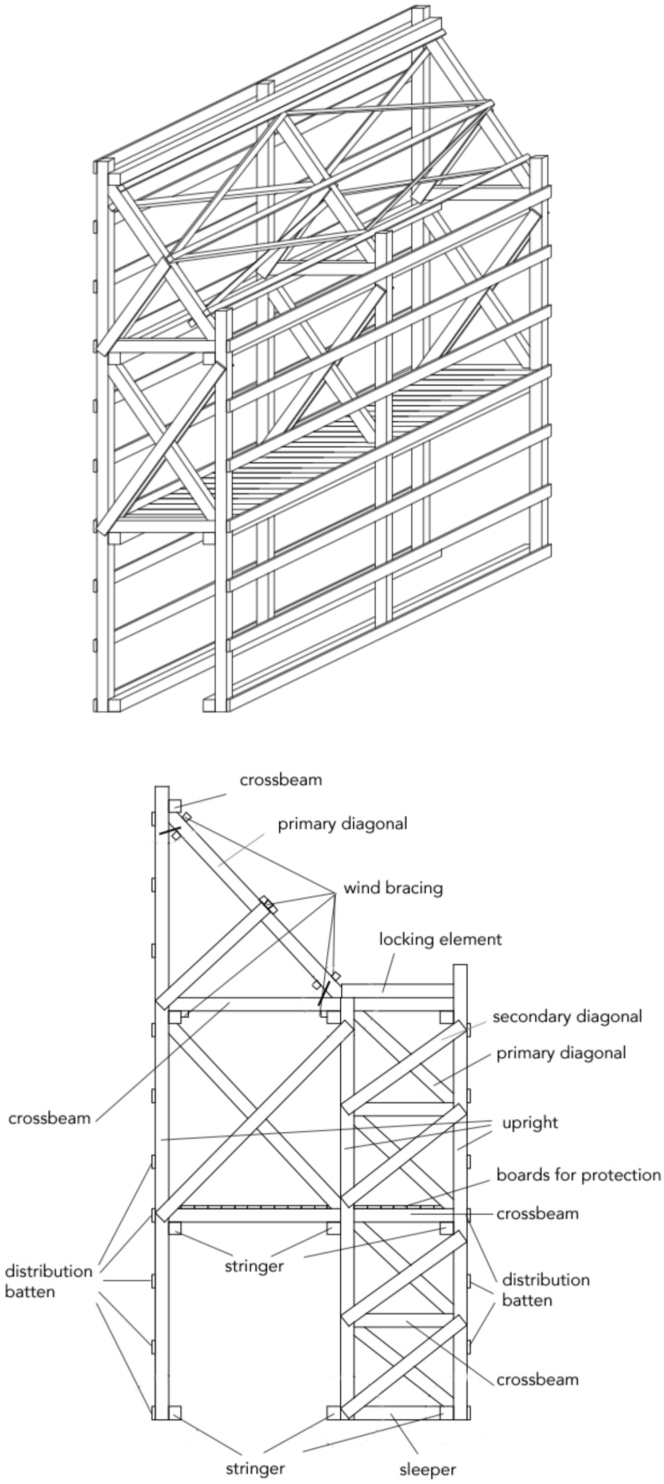


Fig. 44 _Constructive example of a counteracting shoring in wood

4.4 _ Systems to compare

In light of what was analysed and undertaken, a summary diagram regarding the reversibility (R), the flexibility (F), are both evaluated with a scale, ascending from 1 to 10, and to the time of assembly (T.M.)/disassembly (T.S.) evaluated in minutes and hours.

System	R.	F.	T. M.	T. S.
Tubes-clamps	10	10	20 min/sqm	18 min/sqm
Multidirectional	10	4	15 min/sqm	13,5 min/sqm
Modular prefabricated towers	8	8	60-30 min/sqm	60-30 min/sqm
With steel cables				
Bullonatura	10	8	50-40 min/sqm	45-35 min/sqm
Screwing	8	8		
Nailing	5	6		
Welding	2	5		
Polyester bands				
0-5 meters	10	6	40min/cad	36min/cad
5-10 meters			48min/cad	43min/cad
> 10 meters			55min/cad	50min/cad
Wooden systems				
1° use				
Pinning	10	8	5-3 h/mc	5-3 h/mc
Screwing	8	8		
Nailing	5	6		
Stapling	4	6		
2° use and subsequent				
Pinning	10	4	5-3 h/mc	5-3 h/mc
Screwing	8	4		
Nailing	5	3		
Stapling	4	3		

The systems that have a greater reversibility are tube-clamp, multidirectional, systems with steel cables joined by means of bolting, the polyester bands and wooden systems joined by pins. The steel cable systems whose elements are joined by welding have minimum reversibility. The most flexible system is tube-clamp. Not by chance, it has found a wide application in safety works, while the least flexible systems are the multidirectional, because of their technological characteristics and the wood systems at their second use or next, due to the successive reduction of the size of the elements. The system that has a greatest rapidity in assembly and disassembly is multidirectional.

NOTES

1. *Dates are are updated to 23/03/2013*
2. *In the Prezzario Regionale Abruzzo 2013 (Price list of Abruzzo Region 2013) we have been taken into account the prices P.02.10.20.a, P.02.10.30, P.02.10.50, P.02.10.70, P.02.10.100.a, P.02.10.120.a, P.02.10.120.d*
3. *Le opere provvisionali nell'emergenza sismica – Mario Belizzi –Agenzia di protezione civile, Servizio Sismico Nazionale – 2000.*
4. *Terremoto Abruzzo: procedura per la messa in sicurezza di manufatti edilizi in emergenza sismica – Prot. DICOMAT VVF n.860 del 06/05/2009 – Capo del Dipartimento della Protezione Civile.*
5. *Schede Tecniche Opere Provvisionali – Ministero dell'Interno – Corpo Nazionale dei Vigili del Fuoco - Nucleo Coordinamento Opere Provvisionali.*
6. *Manuale delle opere provvisionali urgenti post-sisma – M.Dolce – Convenzione tra il Dipartimento Protezione Civile Ufficio Servizio Sismico Nazionale e l'Università degli Studi della Basilicata.*
7. *Reference data: www.fracasso.it, www.pilosio.com*
8. *Reference data: www.condorteam.com. We emphasise that while in elevation the step of the joint is always of 50 cm, for what concerns the horizontal elements, they undergo minimum dimensional changes according to the manufacturer. It has been taken to refer the Condor as it has a very large components and, therefore, it contemplates the many possibilities present in L'Aquila. Reference images: www.condorteam.com, www.mercegaglia.com*
9. *Reference data: www.ceccantini.it*

5_EXAMPLIFYING INTERNATIONAL PROJECTS

5.1_The situation of international research

After studying the methods of selective demolition and identifying construction systems used for safety, good examples were sought in international projects using components similar to those used for safety. The analysis does not cover only works made with elements of reuse, but the choice was made based on typological, geometric, dimensional and material analogies of the components used.
In particular, examples both of interventions aimed at the restoration of existing buildings and of temporary structures were analysed. This research elucidates possible ways to reuse materials resulting from the selective demolition of safety systems in L'Aquila and to also identify the design potential of components both from a compositional and technological point of view. The choice of building systems is inherent to the requirements that the intervention must meet in terms of flexibility, reversibility, construction time and comfort. Among the cases analysed, there is, however, the reuse of elements especially when the conformation of the constructive system and its components is highly reversible (examples include tube-clamp systems or multidirectional systems). Therefore, the reversibility is an incentive to reuse as it facilitates the dismantling operations, increases the possibility of separation between different materials and ensures the integrity of the components, thereby increasing their residual performance. Even in case of recovery or reinforcement, especially for interventions made in recent years, there is attention to design and the reversibility of the system.
Since 2010, the trend is to use the building systems typically employed in construction sites such as formwork, telescopic props, tube-clamp system and multidirectional system for the definition of architectures with different functions. In some cases, it is a change of function in the temporary field as they retain their temporary nature, such as in the case for the following projects: Eat House, Pavilion Humanidade and Studio East Dining. The use of these systems allows for the combination of reversibility, typically a characteristic of temporariness, with the facility and speed of assembly, which are typical of the systems used on construction sites where time represents a significant economic gain or loss. In fact, comparing these systems with systems traditionally used in temporary structures (e.g. tents and containers) that have the same characteristics in terms of reversibility, facility, and speed of assembly, the systems used in-site have a higher performance in terms of bearing capacity, construction flexibility, adaptability and versatility for implementation with elements that are different from them. For example, the multidirectional system is used as a supporting structure in many of the case studies described, but the horizontal and vertical closures are made differently: in the Eat House they are made with plastic crates filled with sacks of earth, whereas in the project Les Grandes Tables de l'Ile they are made with wooden planks, in temporary pavilion GJL Architekten they are made with aluminium foil fabric. These closures ensure a comfortable environment that is different from the function that houses the building and the time of use. In other cases, constructive systems typically employed on construction sites are used with stable function in the recovery of existing buildings in order to redefine the interior of the space. The motivation towards sustainable design is combined with a change of the conception of the house leading to the definition of spaces that can be subject to dimensional changes depending on their intended use and changing needs of the users. The flexibility of use sought in the space finds an answer in the constructive flexibility of the systems generally used in the construction site. For example, in the project House Rot by Ellen Berg of J. Vylder, I. Vinck, and J. Taillieu, the flexibility allows a different use of space in the winter and summer months, thereby increasing comfort for the users through the transformation of the greenhouse into an open space. Conversely, in the project The difference of Ebitsuka of 403 Architecture, the use of modular systems with tubes-clamps allows for the expansion of space, thanks to the transformation of the underside of the floor in wardrobes.

Gilmour Road, R. Murphy, Edinburgo, 1994

The intervention consists of the expansion of a two-family Victorian style house.
A partial demolition of an area was made in order to insert a new volume, which houses the kitchen.
The new roof rests on steel beams and vertical walls are made with western red cedar panels.
The former kitchen was transformed into a dining room.
The extension is also equipped with a balcony and with a scale, which allows access to the underlying garden.

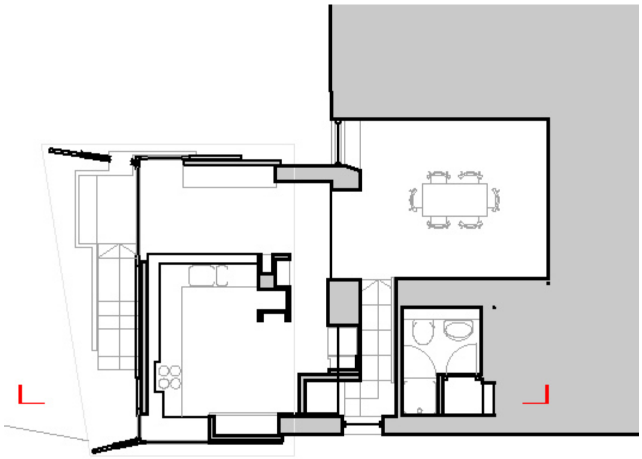
Winter temperatures:
min: 1° C
max: 5° C
Summer temperatures:
min: 10° C
max: 17°C

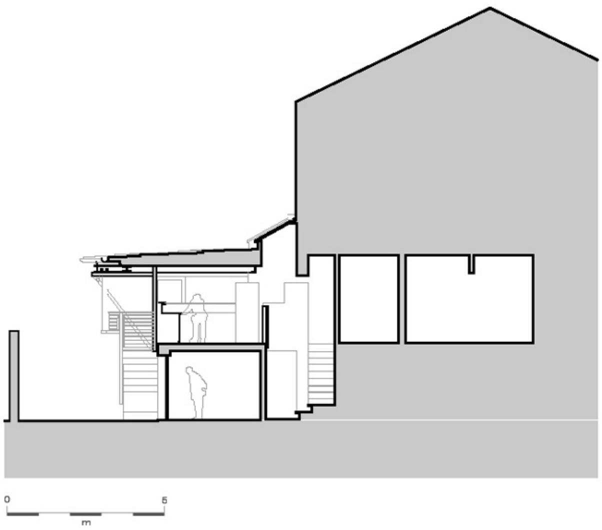
Flexibility of building system:

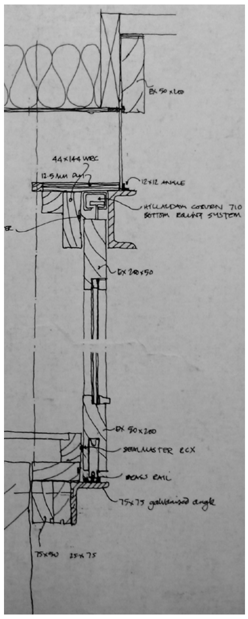
Reversibility of building system:

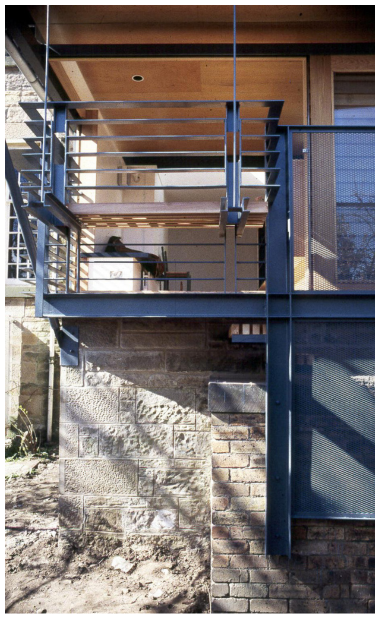
Time of assembly/disassembly:

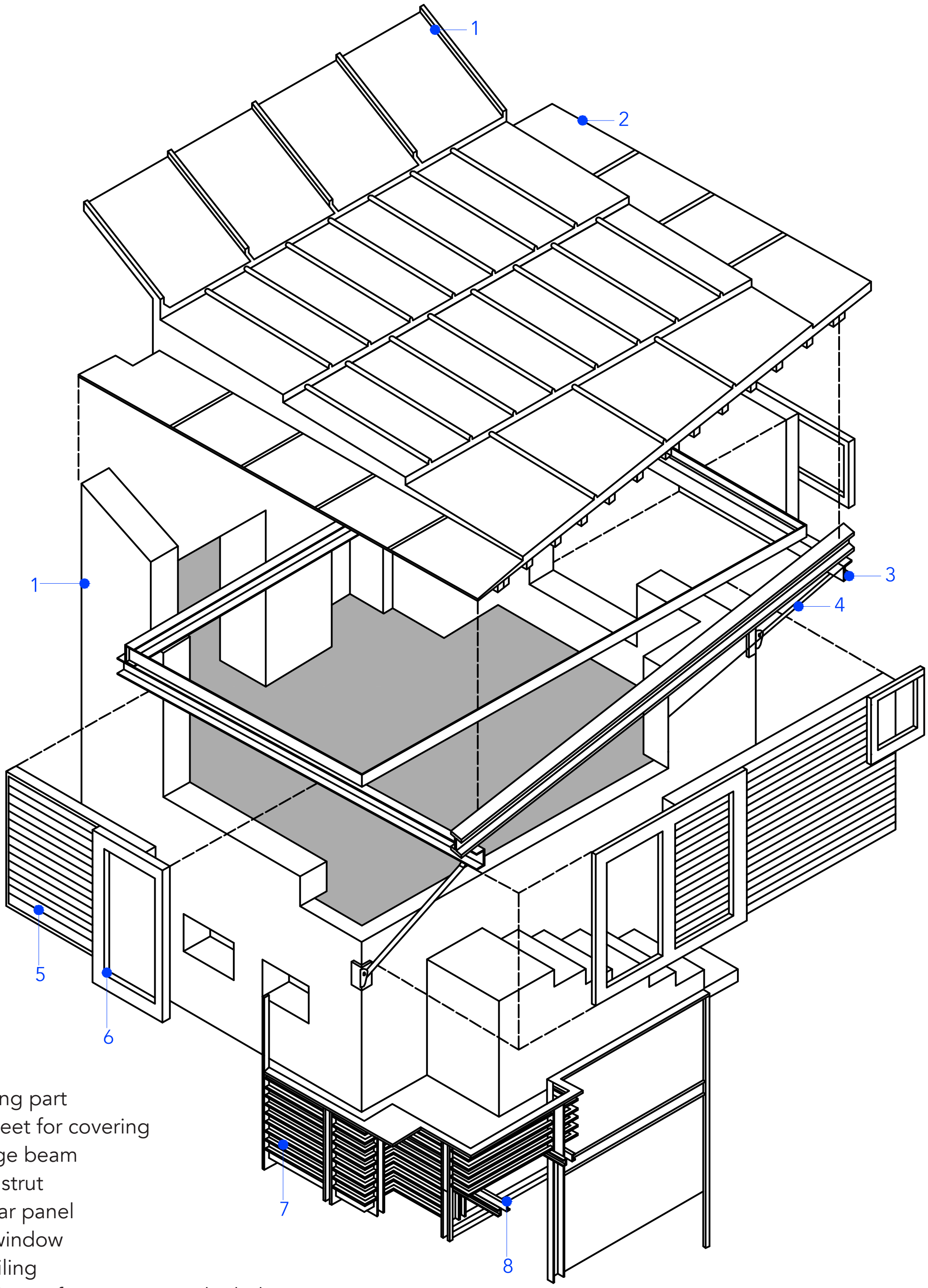
Facility of assembly/disassembly:



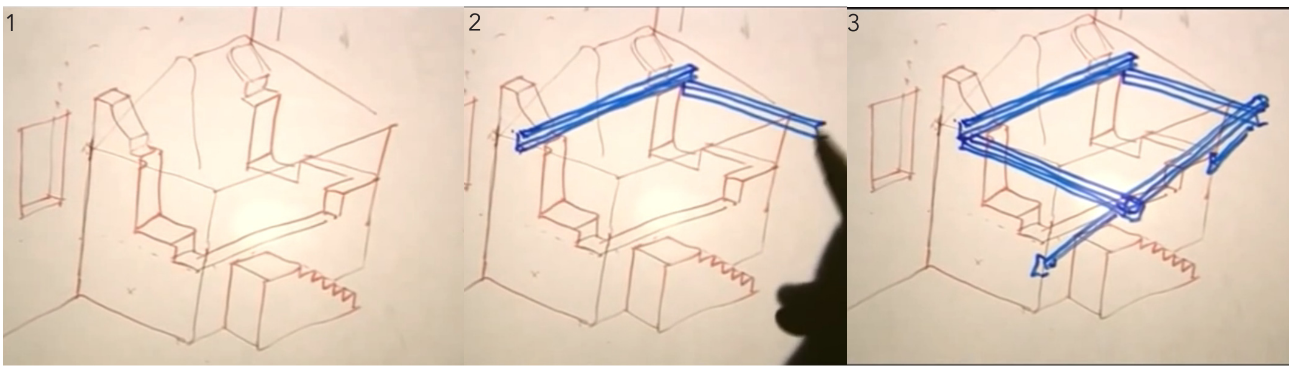








1-Preexisting part
2-Metal sheet for covering
3-UPN edge beam
4-Support strut
5-Red cedar panel
6-Sliding window
7-Metal railing
8-Coupled UPN for supporting the balcony

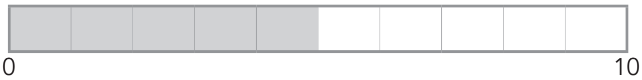


Centro di arti visive, Joao Mendes Ribeiro, Coimbra, 2003

The College of Visual Arts, built in 1548, is attributed to Diogo Castiho. The College of Visual Arts concentrates in the west part of the Arts Centre of Coimbra. Until 1821, it was occupied by the Court of the Holy Office. After the liberal revolution, it became a Republican Centre and was then converted into a military base. In 1996, the Municipality of Coimbra commissioned Ribeiro for the preparation of exhibition "Heaven and Hell" by Joel Peter Witkin to be prepared on the ground floor. This exhibition led to the recovery process of the building. Ribeiro on the one hand gives new force to the history of the building, and on the other hand, makes the new interventions recognisable. The project is physically separated from the existing building and many spaces are eliminated by wooden partitions. The historical remains present on the ground floor have been preserved with raised wooden flooring, which is easily reversible. In the regeneration of the west part, the construction systems and the original materials form finishes to coatings that have been preserved using traditional building techniques. Even the trusses, when damaged, were strengthened with wooden pine elements.

Winter temperatures:
min: 6,5° C
max: 15° C
Summer temperatures:
min: 15° C
max: 28°C

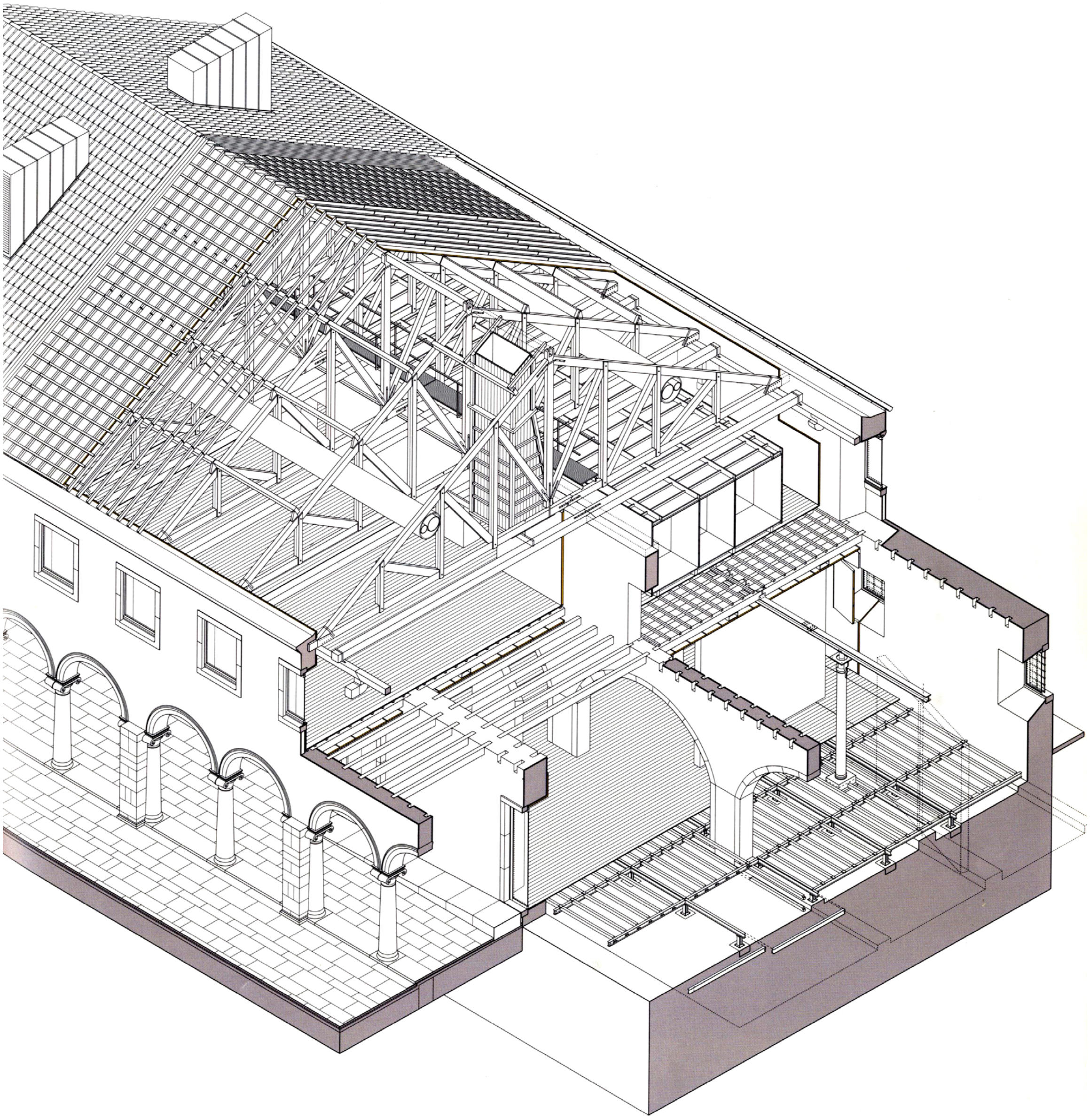
Flexibility of building system:



Reversibility of building system:

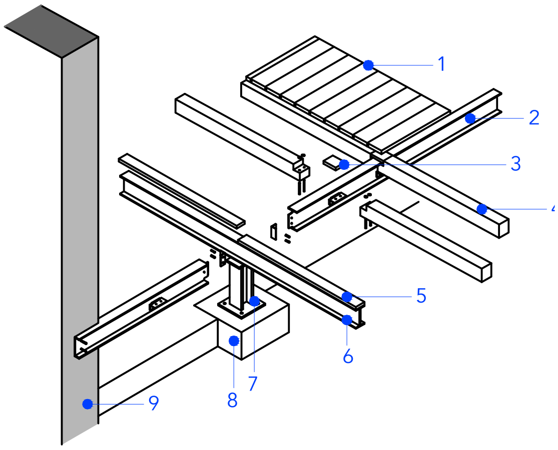
Time of assembly/disassembly:

Facility of assembly/disassembly:

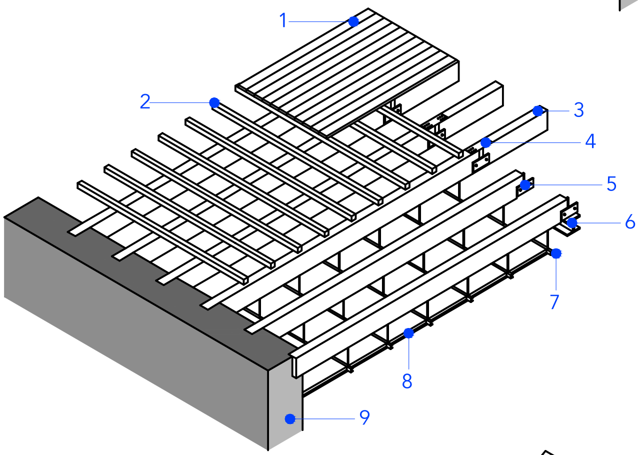


HORIZONTAL LOWER CLOSURE

1-Pine boards, 22 mm
2-IPE 140 beam
3-Wooden compensation element
4-Wooden beam
5-Wooden compensation element
6-IPE 140 beam
7-HEA 100 pillars
8- Reinforced concrete foundation 40x40x20 cm
9- Pre-existing wall



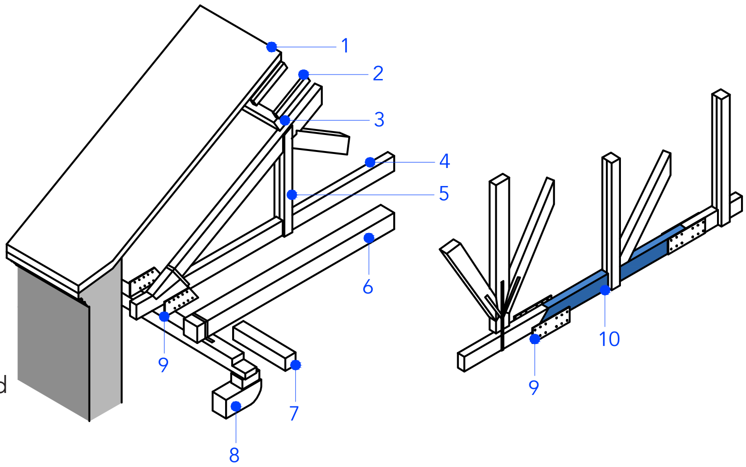
HORIZONTAL INTERMEDIATE CLOSURE



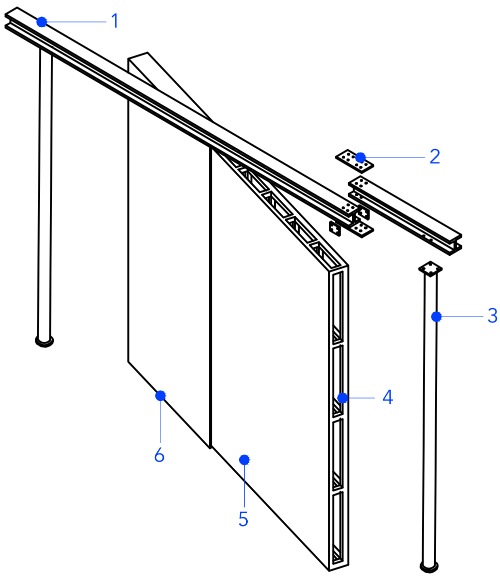
1-Pine boards, 22 mm
2-Wooden element
3-Wooden beam, 12 x 24 cm
4-Steel plate
5-Steel bracket
6-HEA 100 beam
7-Ceiling C profile
8-Countertop
9- Pre-existing wall

HORIZONTAL UPPER CLOSURE

1-Covering
2-Wooden common rafters
3-Wooden purlins
4-Wooden bottom chord
5-Wooden web
6- Reinforced wooden beam
7-Perimetral wooden beam
8-Stone shelf
9-Galvanized steel plate
10-Part of wooden bottom chord



INTERNAL PARTITION



1-HEB 180 beam
2-Steel plate, 12 mm
3-Pillar reinforcement with steel tubular 140, thickness 8 mm
4-Steel structure made with tubular 60x30x3 and 30x30x3 mm
5- Birch plywood, 9 mm
6-Plasterboard

Intermediae Matadero Madrid, Franco e Van Teslaar, Madrid, 2007

The old slaughterhouse of Madrid consists of a complex with more than 20 depots, designed by Luis Bedillo in 1907. The depot 17c has been converted into a Contemporary Culture Centre, thanks to the intervention designed by Arturo Franco and Fabrice Van Teslaar.
Materials arising from industry are used. The UPN 180 steel profiles were used not only with structural function, but also to form furniture and finishes.
The intervention was made with a budget of 700000 euros. The design choice was to leave the breaches on the walls, the cork insulation and the retouches on the pillars.
The technical implants are left outside.

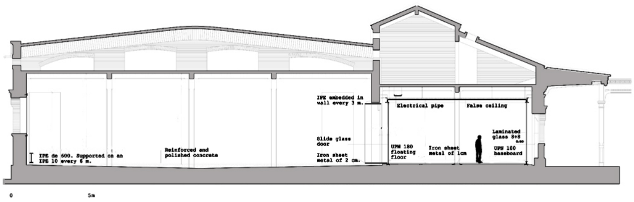
Winter temperatures:
min: 1,8° C
max:: 9° C
Summer temperatures:
min: 16,5° C
max: 28°C

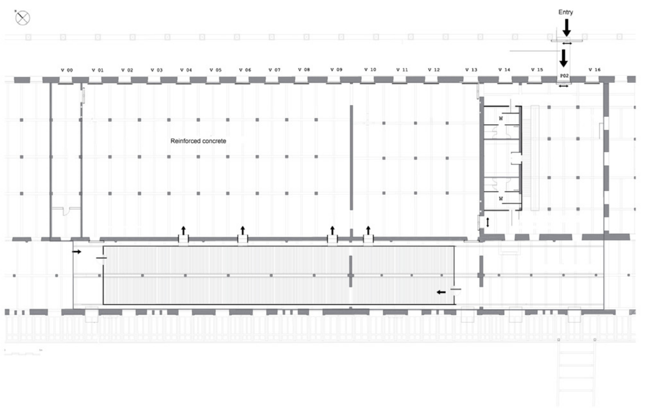
Flexibility of building system:

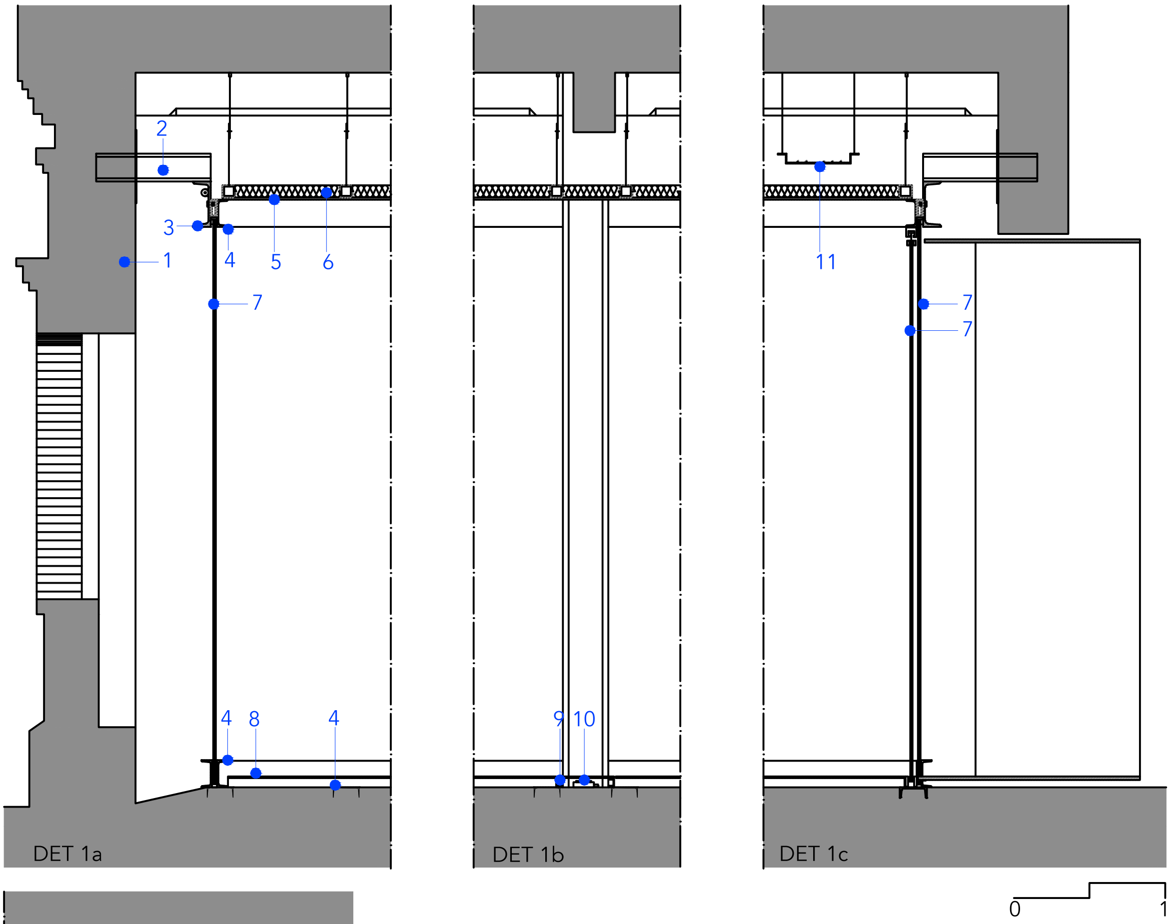
Reversibility of building system:

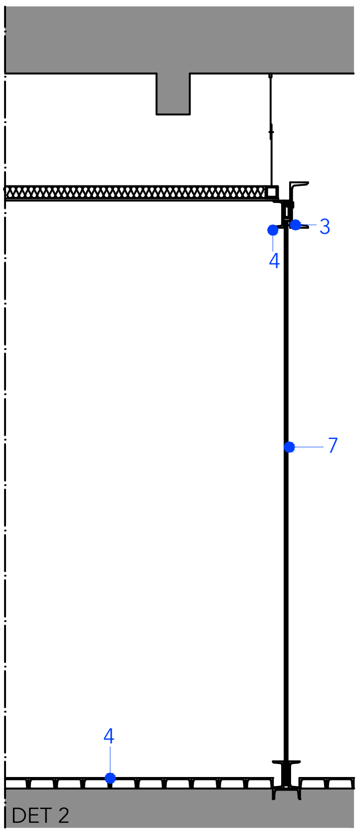
Time of assembly/disassembly:

Facility of assembly/disassembly:

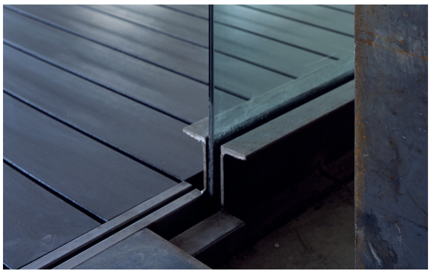


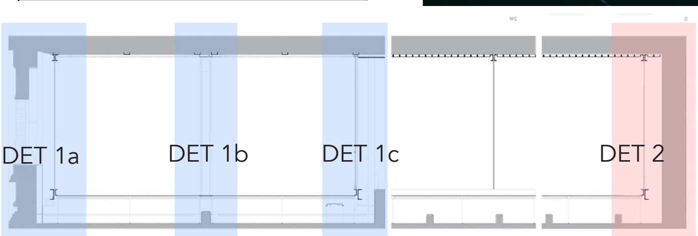






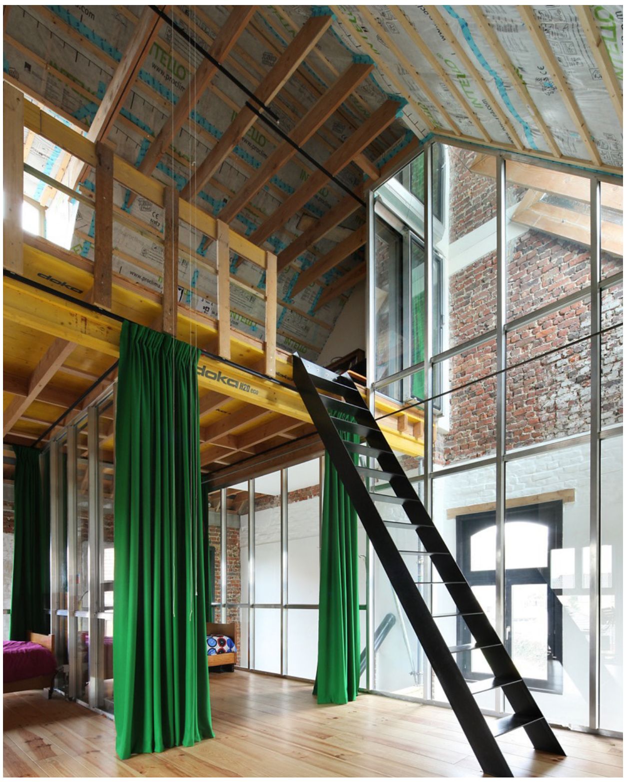
1-Preexisting bearing wall
2-IPE 180 profile
3-UPN 300 profile
4-UPN 180 profile
5-Plasterboard, 12,5 mm
6-Insulation, 85 mm
7-Insulating glass 8+8+8
8-Steel flat, 10 mm
9-C steel profile
10-Electrical installation
11-Profile for electrical installation





House Rot Ellen Berg, Vylder Vinck Taillieu, Oudenaarde, 2011

The recovery of this Flemish building made with bricks is expressed in the evolution of space according to the different ways of living in summer and winter, thanks to the flexibility of use and construction flexibility.
A greenhouse inside the building becomes an open space in the warmer months.
Traditional temporary systems (scaffolding, formwork, etc.) were used in a permanent way in order to increase the sustainability of the intervention through the reduction of the number of processes/works.



Winter temperatures:
min: 1° C
max: 5,5° C
Summer temperatures:
min: 12,5° C
max: 21°C

Flexibility of building system:

0 10

Reversibility of building system:

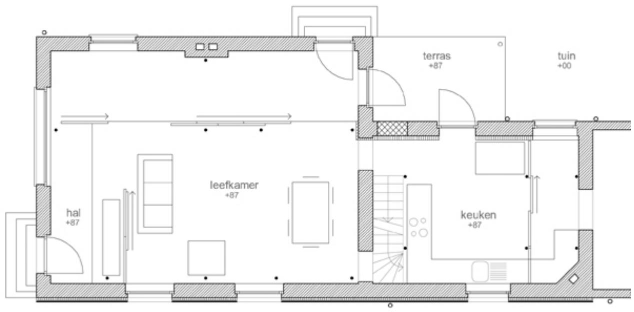
0 10

Time of assembly/disassembly:

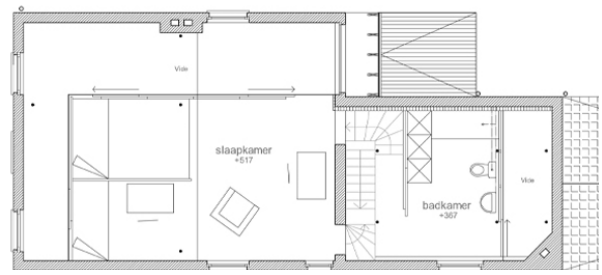
0 10

Facility of assembly/disassembly:

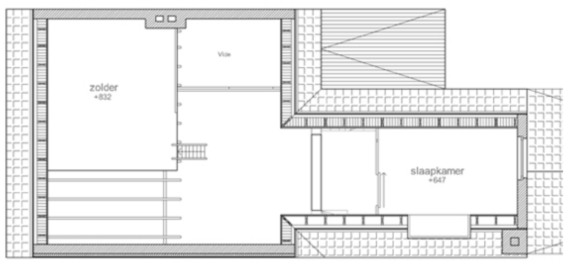
0 10



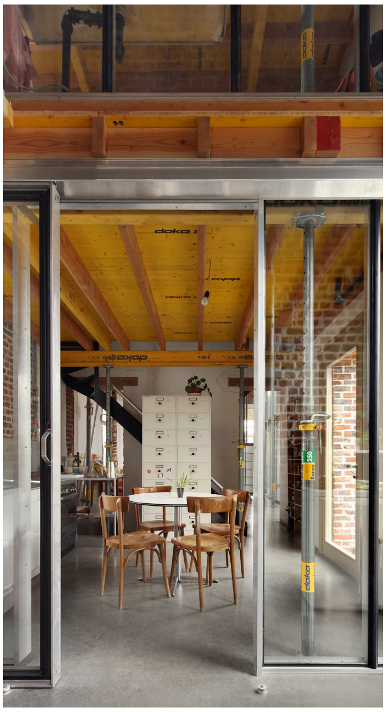
GROUND FLOOR

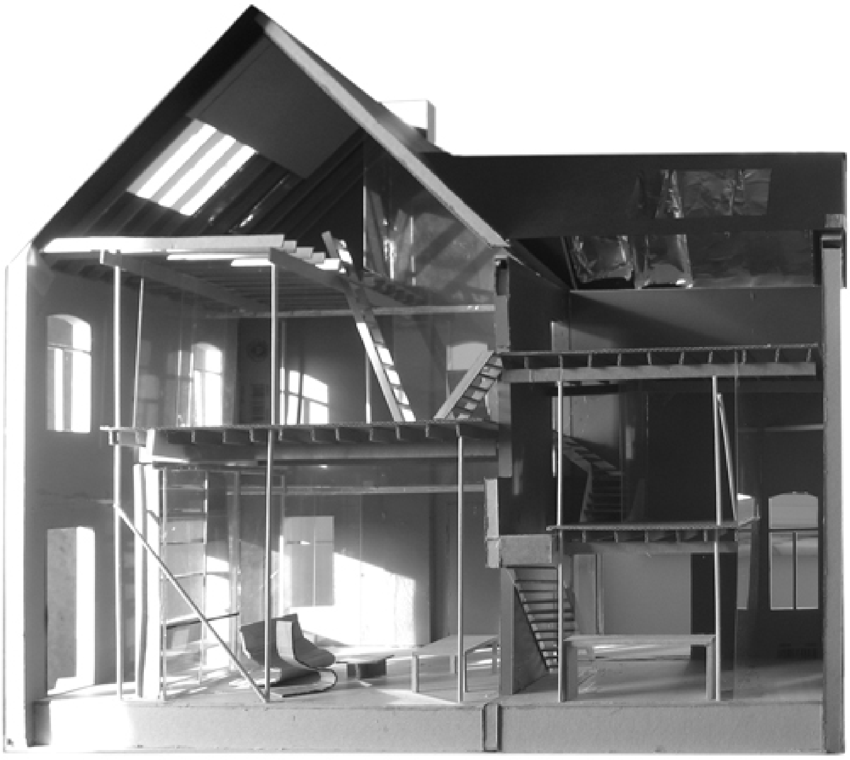


FIRST FLOOR

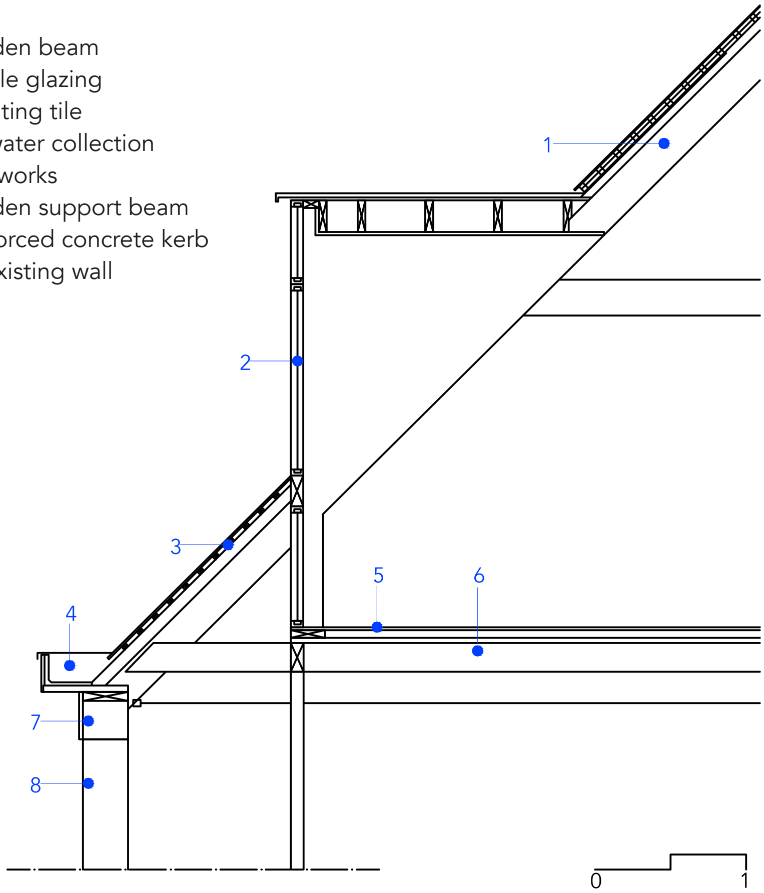


SECOND FLOOR



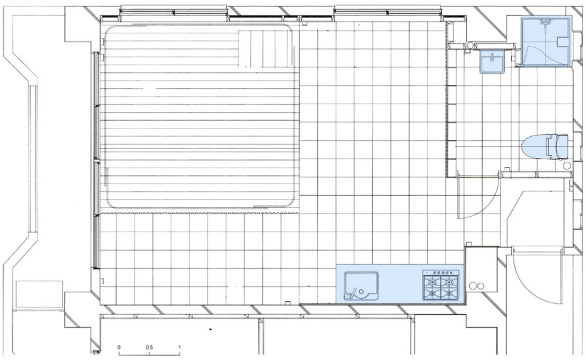


1-Wooden beam
2-Double glazing
3-Insulating tile
4-Rainwater collection
5-Formworks
6-Wooden support beam
7-Reinforced concrete kerb
8-Pre-existing wall



The difference of Ebitsuka, 403 Architecture, Hamamatsu, 2011

The project concerns an apartment located in a ground floor in a residential complex of 3 floors, situated along the river. The discovery of a false floor allowed the expansion of volume of 3.5 cubic metres. The room is divided on two levels. The used materials are derived from previous demolitions. For example, the scale that connects two floors consists of wooden elements that previously supported the false floor.

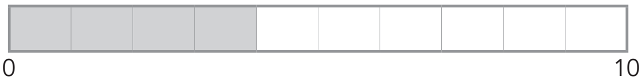


Winter temperatures:
min: 2° C
max: 9,5° C
Summer temperatures:
min: 21° C
max: 28°C

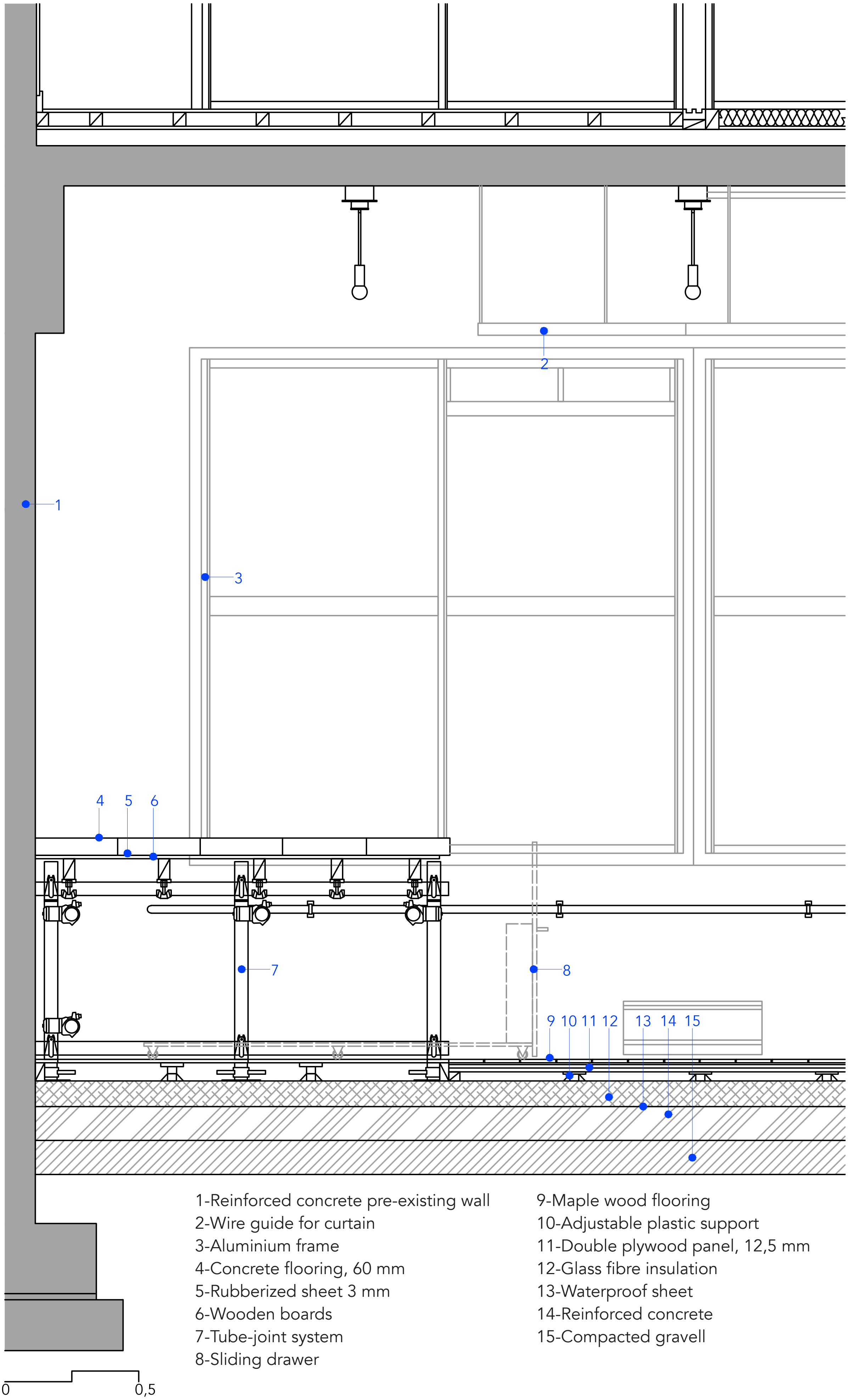
Flexibility of building system:

Reversibility of building system:

Time of assembly/disassembly:



Facility of assembly/disassembly:



1-Reinforced concrete pre-existing wall
2-Wire guide for curtain
3-Aluminium frame
4-Concrete flooring, 60 mm
5-Rubberized sheet 3 mm
6-Wooden boards
7-Tube-joint system
8-Sliding drawer
9-Maple wood flooring
10-Adjustable plastic support
11-Double plywood panel, 12,5 mm
12-Glass fibre insulation
13-Waterproof sheet
14-Reinforced concrete
15-Compacted gravell

Egg 333 Remodeling, Joho Architecture, HwaYang, 2012

The restoration of the building introduces a new skin for the façade, made with wooden elements of two sizes, framed with a metal profile. Similarly, the courtyard is redefined. The outdoor space formed by the accessible roof and by the courtyard are in geometric relation to one another. The mode of cutting wooden elements allows the filtering of light while simultaneously protecting from introspection.

In the courtyard, the existing reinforced concrete slab is covered with wooden profiles, while the enclosure consists of vertical steel profiles for bearing horizontal wooden elements.

Winter temperatures:
min: 0,5° C
max: 8° C
Summer temperatures:
min: 23° C
max: 30°C

Flexibility of building system:

0 10

Reversibility of building system:

0 10

Time of assembly/disassembly:

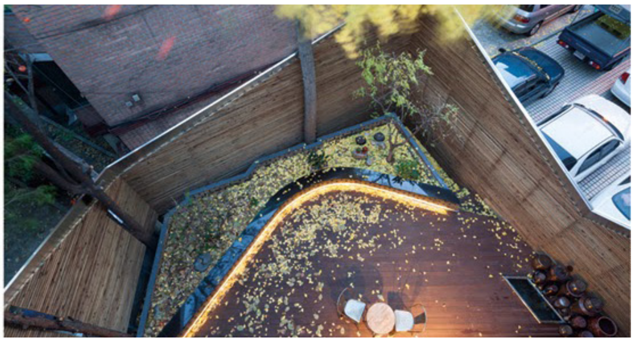
0 10

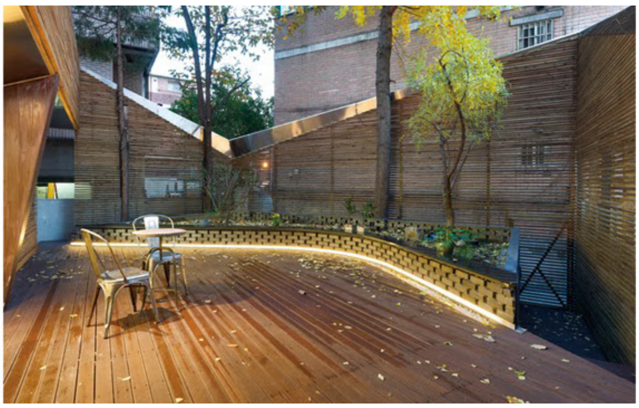
Facility of assembly/disassembly:

0 10

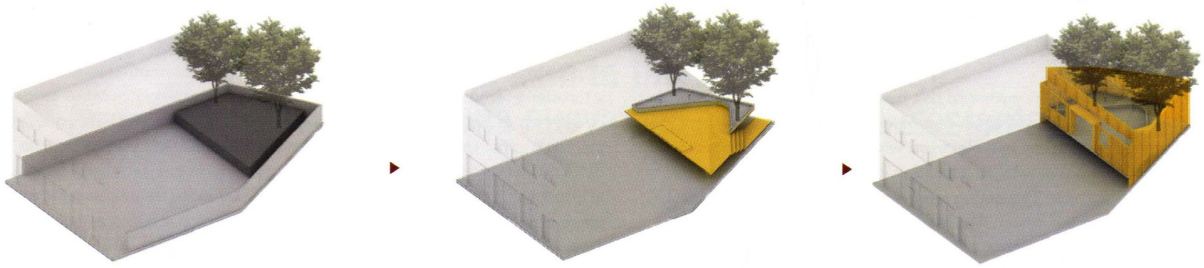
BEFORE

AFTER

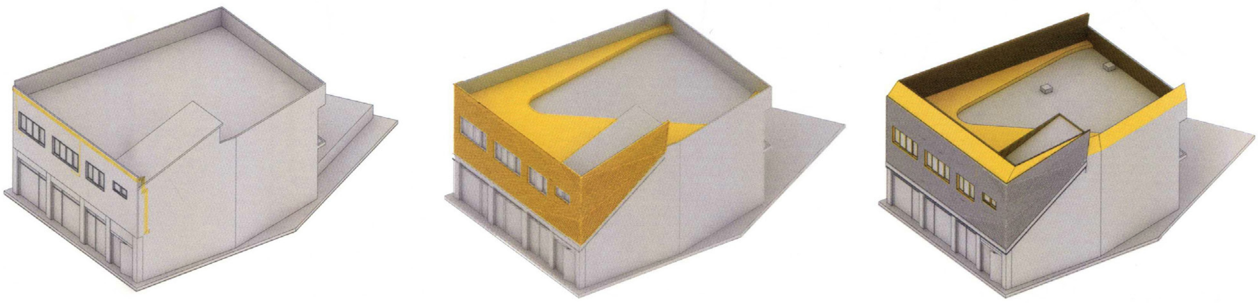




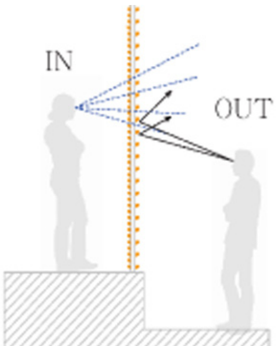
EVOLUTION OF THE COUTYARD



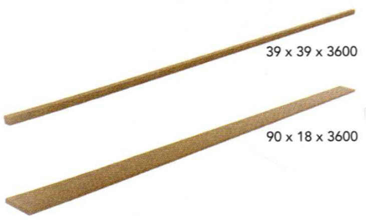
EVOLUTION OF THE FAÇADE



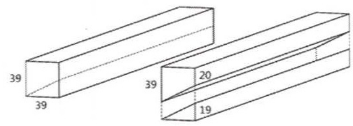
SCHEME OF INTROSPECTION



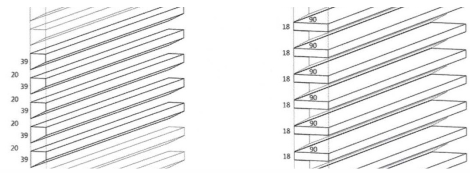
USED ELEMENTS

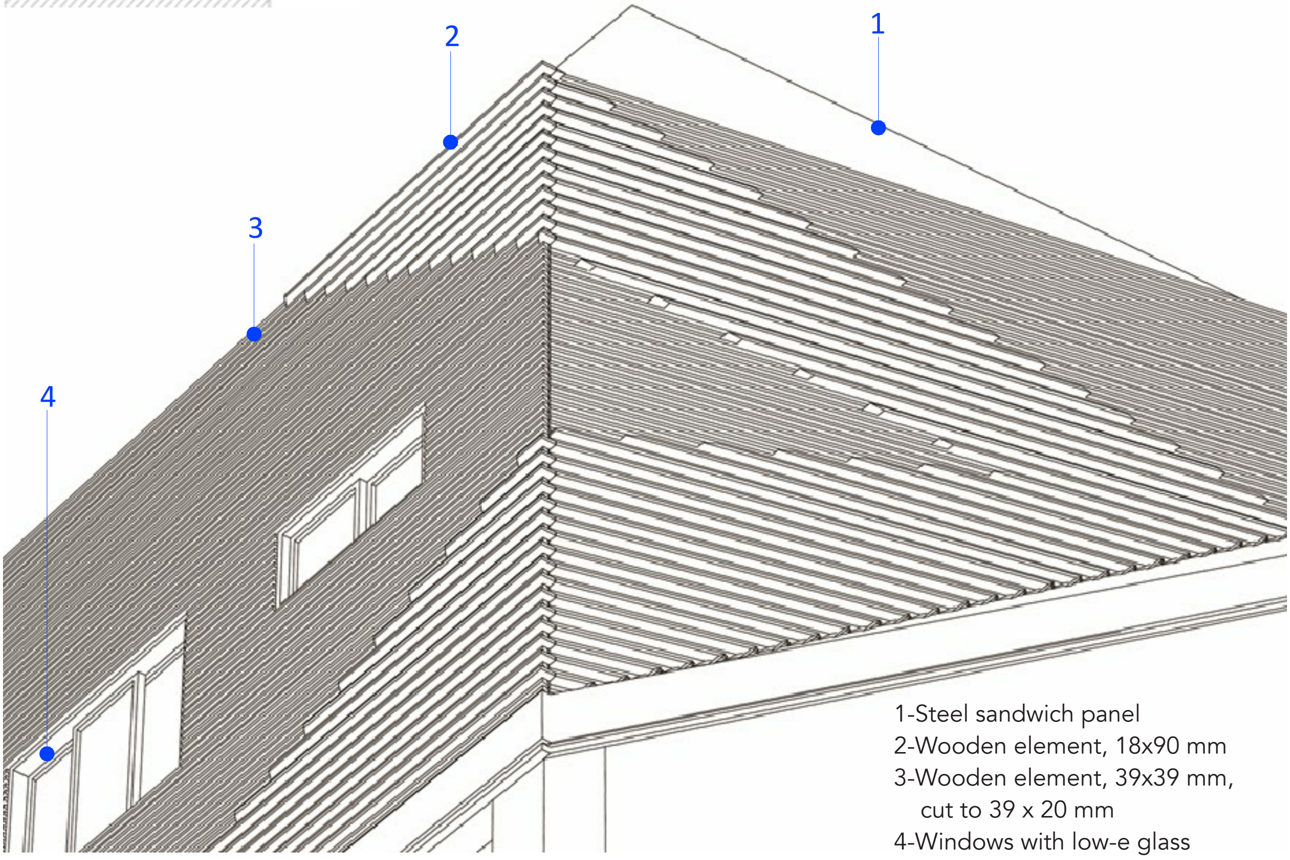


CUTTING MODE



POSITIONING





1-Steel sandwich panel
2-Wooden element, 18x90 mm
3-Wooden element, 39x39 mm, cut to 39 x 20 mm
4-Windows with low-e glass

Padiglione, GJL Architekten, Freiburg, 1998

The Pavilion was designed to host exhibitions, shows and events about architecture. It remembers the shape of the archetypal house.
A double skin covers the bearing structure, built with multidirectional system: one skin is internal and the other external. The type of connections, inherent to the building system used, guarantees the reversibility of the building and the reuse of elements. Screw piles form foundations. The structure has a wheelbase of 2.57x2.57 m.
The double skin is made from a fabric impregnated and coated with an aluminium film. The outer skin is secured with wooden joints, and the interior covering with clips.

Winter temperatures:
min: -3° C
max: 3° C
Summer temperatures:
min: 11° C
max: 21°C

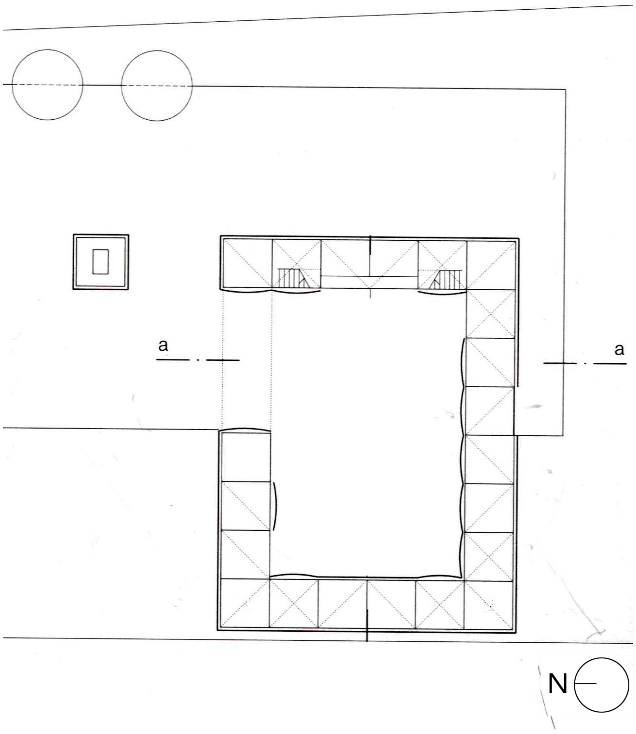
Flexibility of building system:

Reversibility of building system:

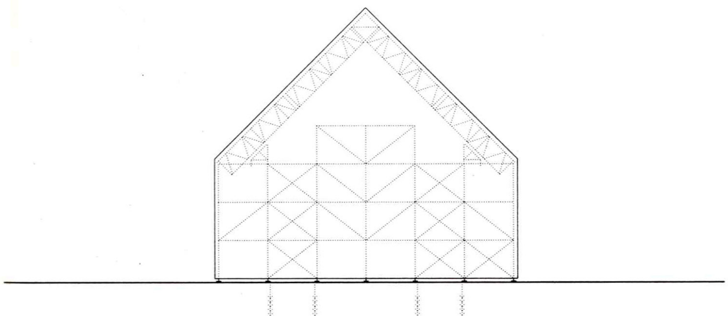
Time of assembly/disassembly:

Facility of assembly/disassembly:

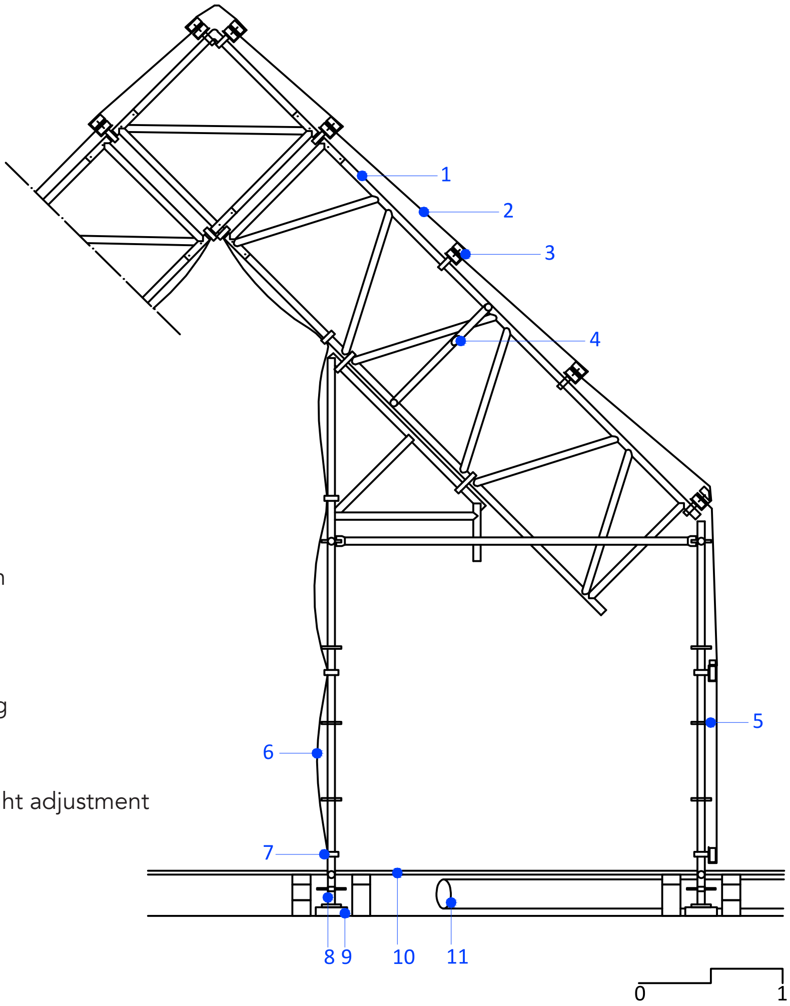
PLAN



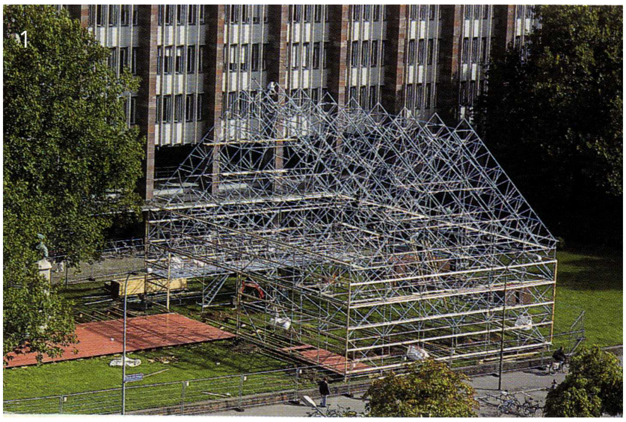
WEST ELEVATION



CROSS SECTION



1-Multidirectional System,
diameter 48.3 mm, thickness 3.2 mm
2-Fabric protected with aluminium foil
3-Wooden element, 9/98 mm
4-Transverse reinforcement element
5-Connection with multidirectional ring
6-Fabric protected with aluminium foil
7-Fixing clip for interior membrane
8-Multidirectional base plate with height adjustment
9-Anchor base
10-Flooring with formwork boards
11-Heating



Eat house, Atelier Gras, Rotterdam, 2010

The project aims to encourage a direct relationship between producers and consumers and transform, thanks to the presence of a vegetable garden, a temporary home into an edible house. Eathouse is a modular system where the frame in tubes of tube-clamp system and of multidirectional system is dimensionally coordinated with plastic boxes, which are commonly used in collecting and selling fruits and vegetables. The system introduces a new way of thinking about the garden that can be accessible to everyone and everywhere, due to its temporary and reversible nature.

Winter temperatures:
min: 0,8° C
max: 5,5° C
Summer temperatures:
min: 12° C
max: 19,8°C

Flexibility of building system:

0 10

Reversibility of building system:

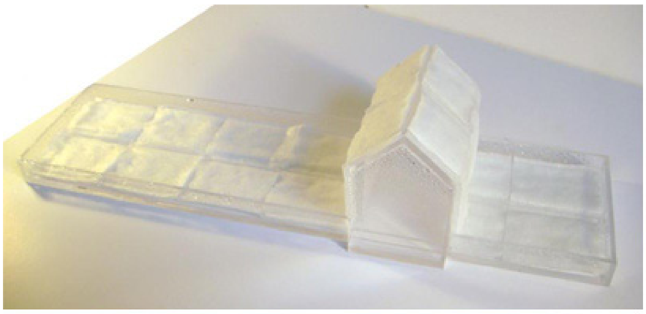
0 10

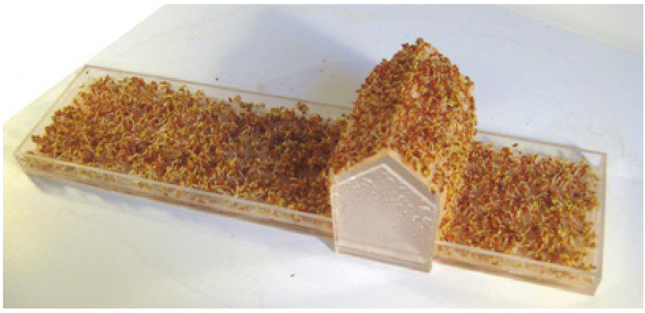
Time of assembly/disassembly:

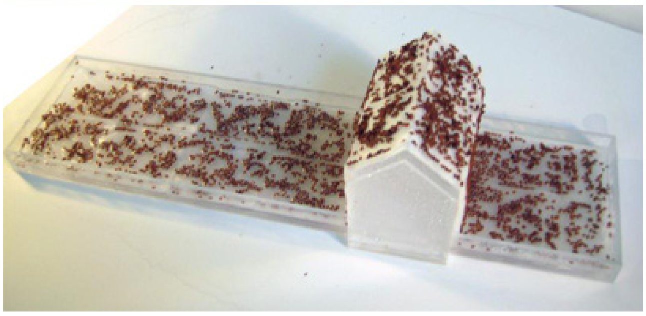
0

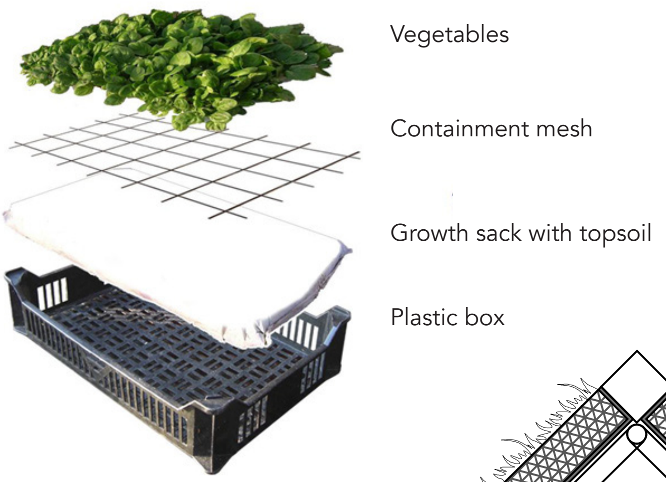
Facility of assembly/disassembly:

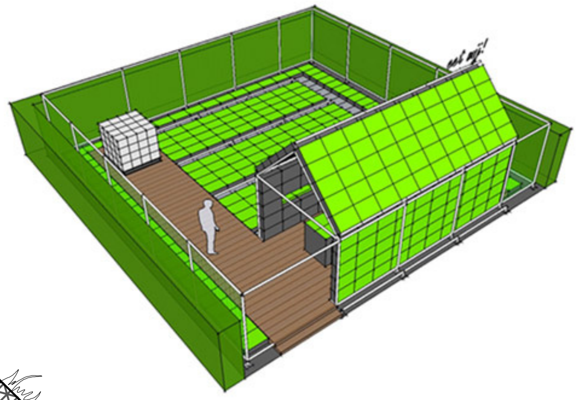
0 10

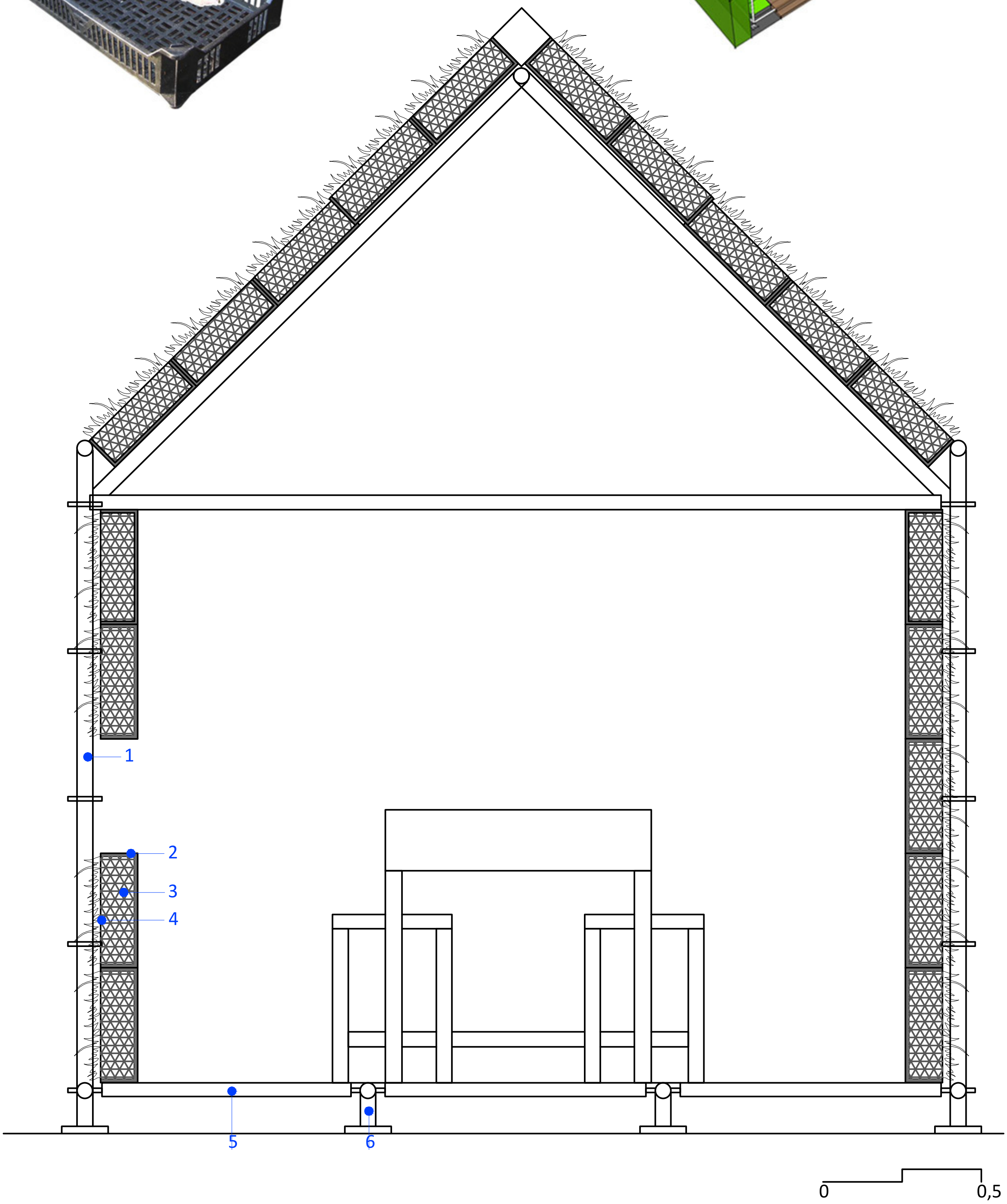








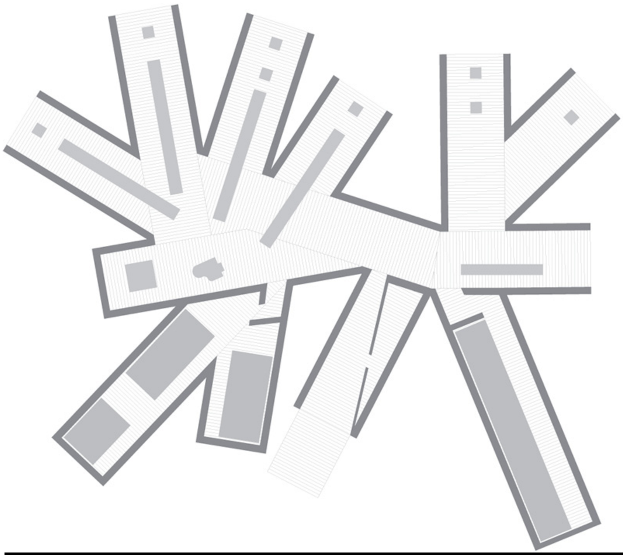


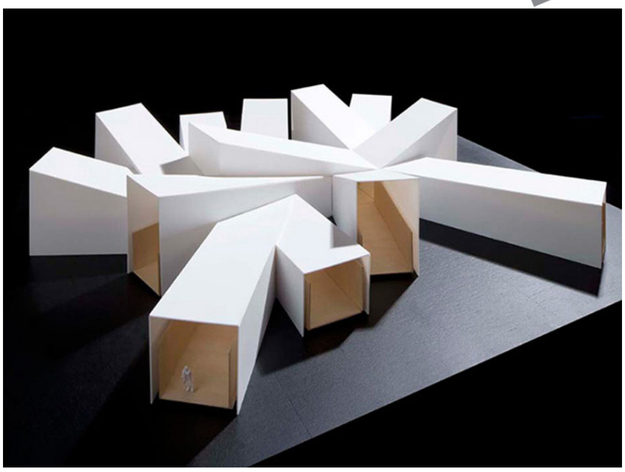


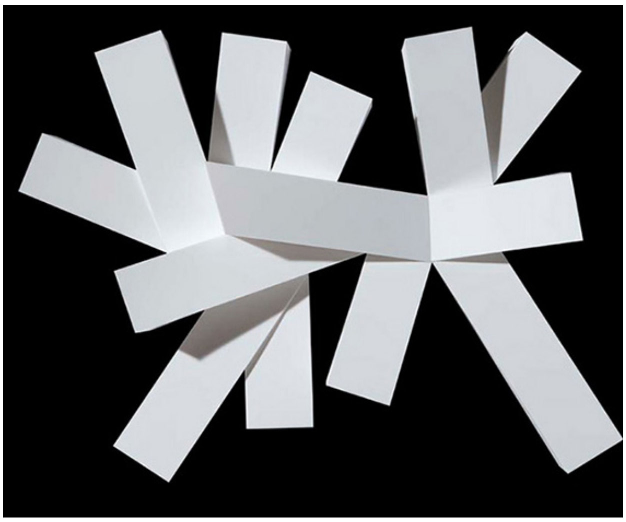
1-Multidirectional system,
diameter 48.3 mm, thickness 3.2 mm
2-Plastic case
3-Soil
4-Metal mesh
5-Metal scaffolding table
6-Multidirectional base plate
with height adjustment

Studio East Dining, Carmody Groarke, Londra, 2010

The temporary restaurant designed by Carmody Groake during the 2012 Olympic Games in London consists of a frame in tubes (about 3500), horizontal and vertical closures and fittings that consist of formwork boards (about 2000). Outside, the metal structure is covered with industrial polyethylene translucent sheets.
The shape of the restaurant is designed to create privileged optical cones over the city. Three of the seven existing volumes host the kitchens and services.





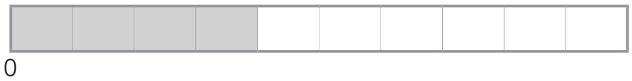


Winter temperatures:
min: 2° C
max: 8,3° C
Summer temperatures:
min: 12,5° C
max: 22°C

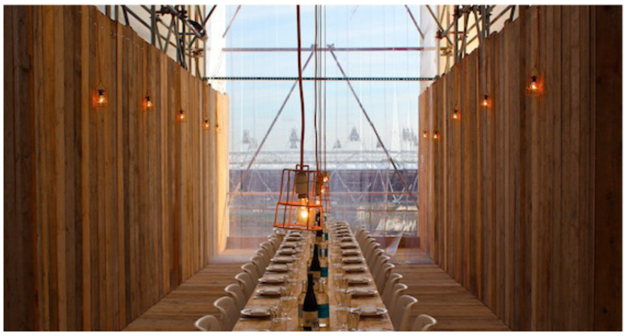
Flexibility of building system:

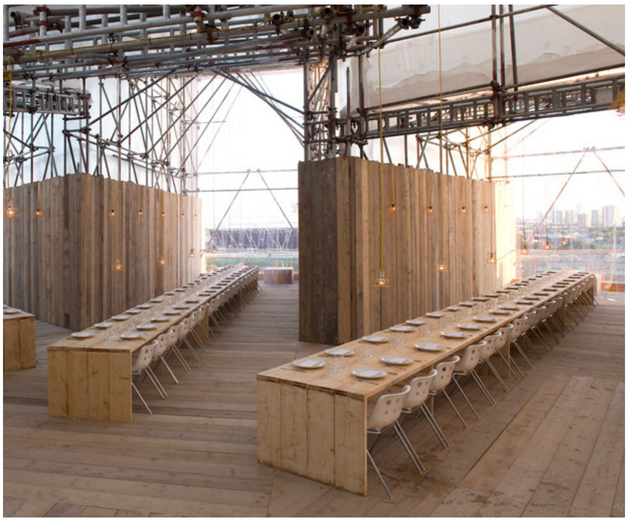
Reversibility of building system:

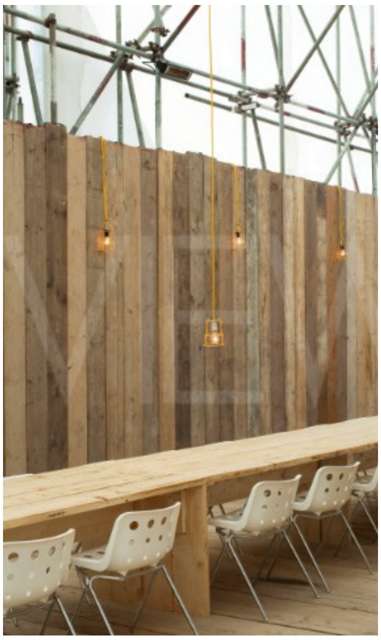
Time of assembly/disassembly:

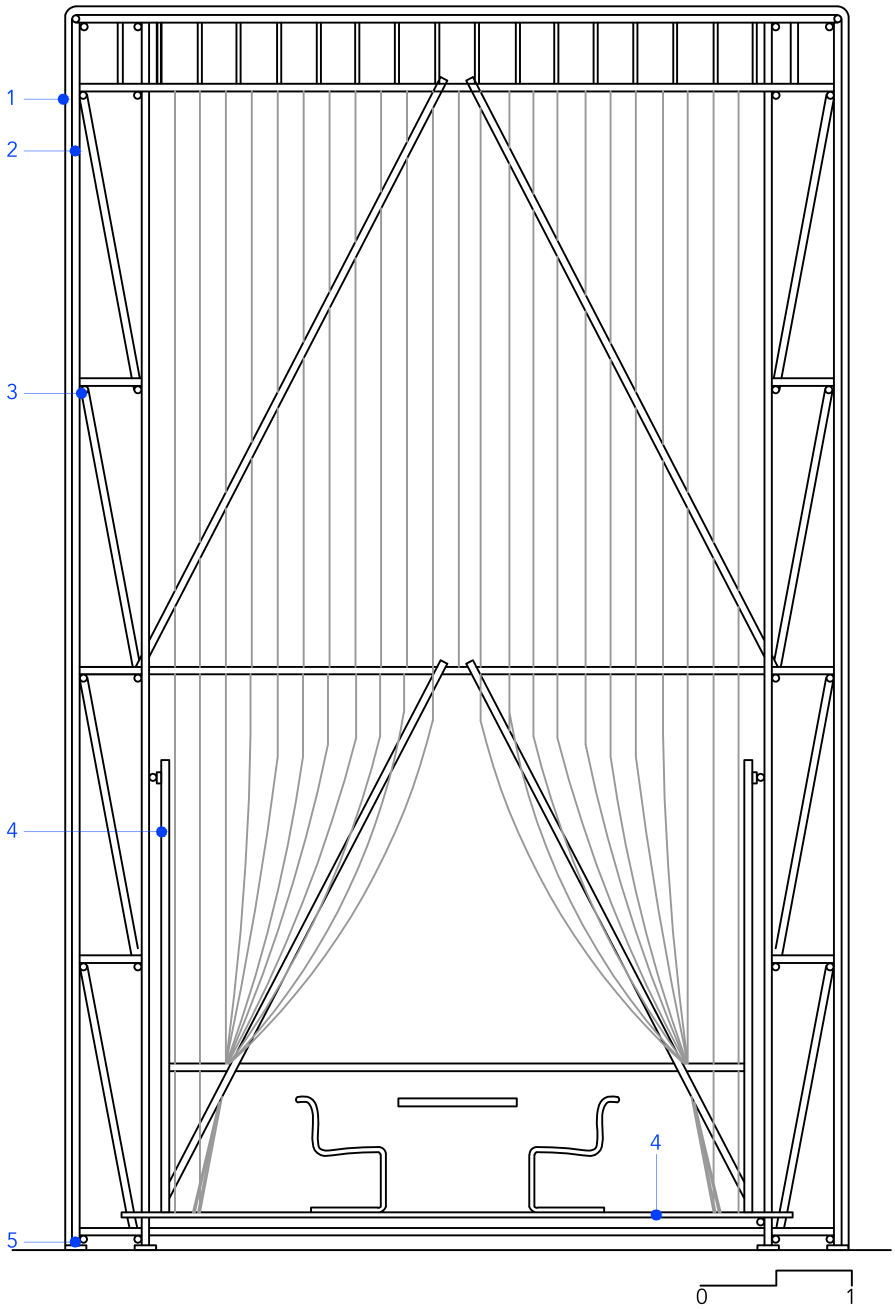


Facility of assembly/disassembly:









1-Industrial polyethylene translucent cloth
2-Tube-clamp system
3-Swivel clamp
4-Wooden board for formwork
5-Base plate with height adjustment

Les Grandes Table de L'Ile, 1024 Architecture, Parigi, 2011

The bar-restaurant is built with a multidirectional system, tube-clamp system, wood fiber panels and containers.
It can accommodate up to 120 guests, offering an area of about 300 square metres.
The structure rests on the bases of the multidirectional system. The grid is mounted first and, then, vertical and horizontal closures are placed inside. These are made with sandwich panels (wooden covering and aluminium structure). The wooden struts, which are nailed sandwich panels, are anchored through the eyelets of the multidirectional system to the bearing structure.

Winter temperatures:
min: 1,3° C
max: 6,5° C
Summer temperatures:
min: 13° C
max: 24°C

Flexibility of building system:

0 10

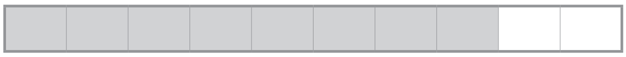
Reversibility of building system:

0 10

Time of assembly/disassembly:

0

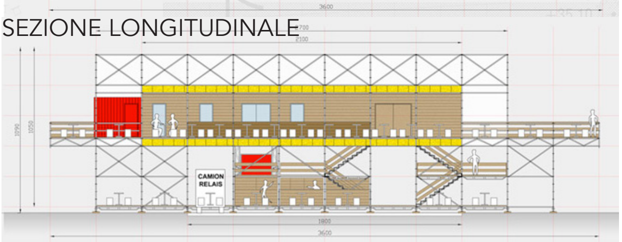
Facility of assembly/disassembly:

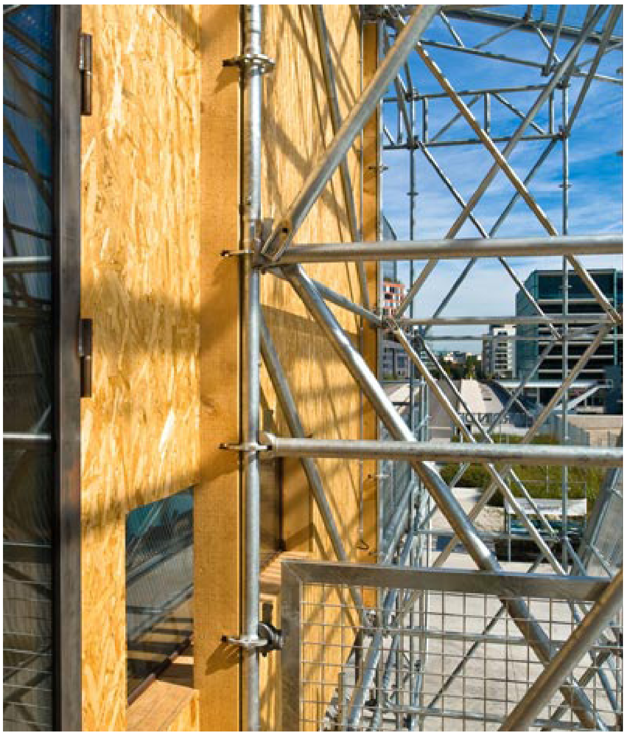


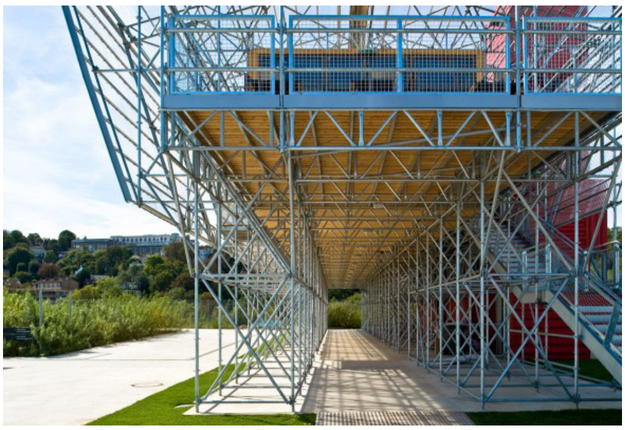
0 10

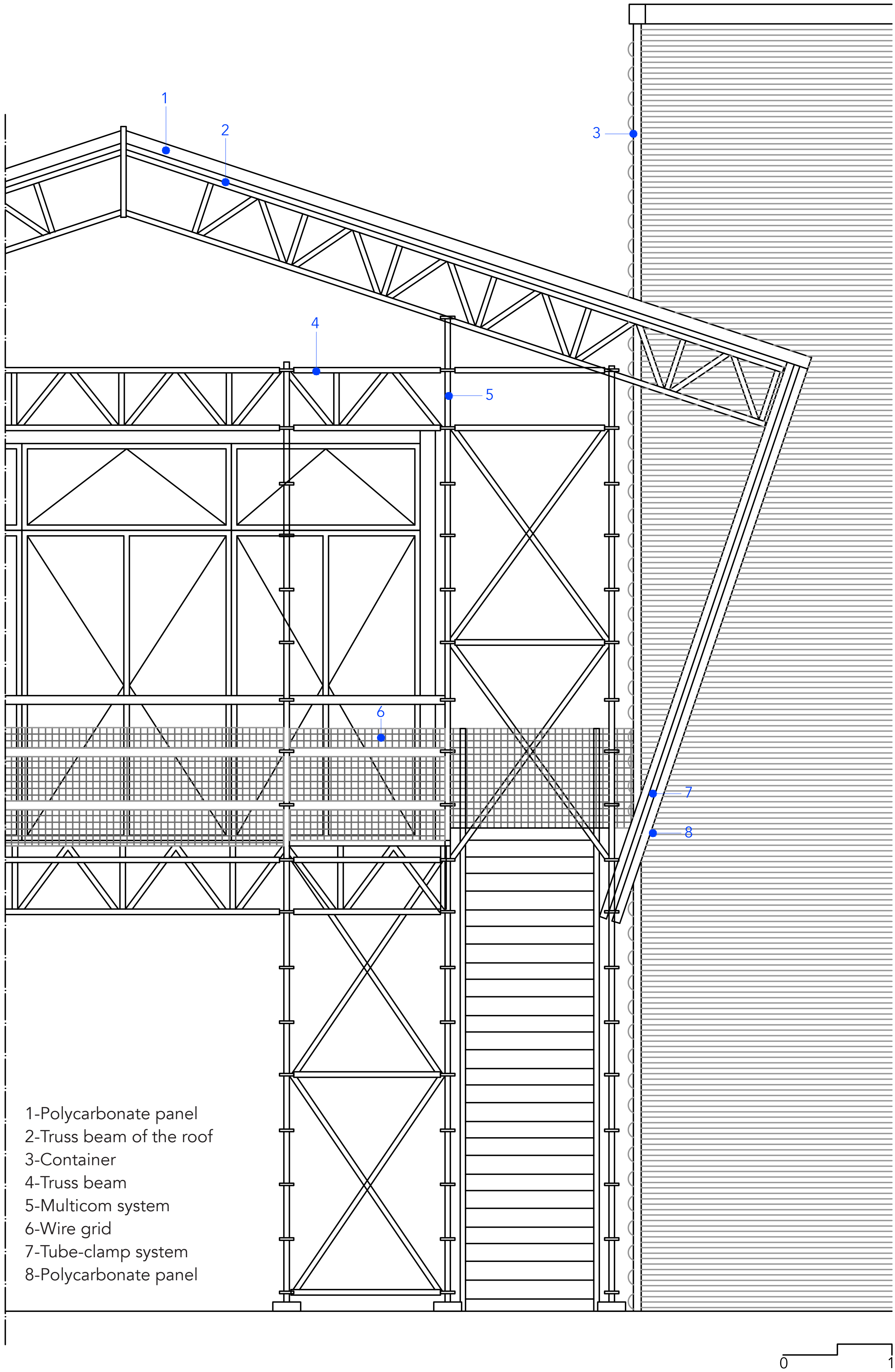
PIANTA

SEZIONE LONGITUDINALE







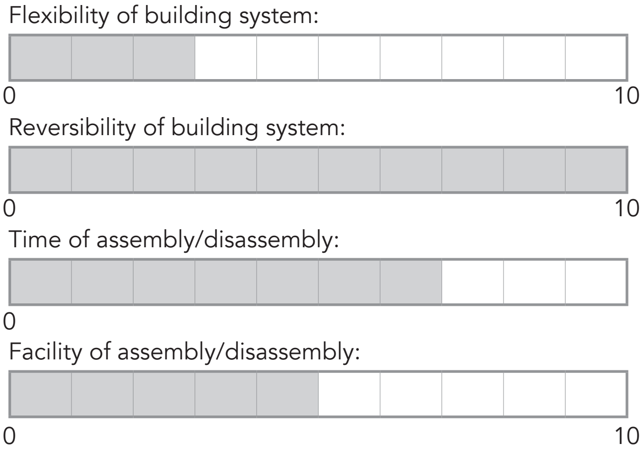


1-Polycarbonate panel
2-Truss beam of the roof
3-Container
4-Truss beam
5-Multicom system
6-Wire grid
7-Tube-clamp system
8-Polycarbonate panel

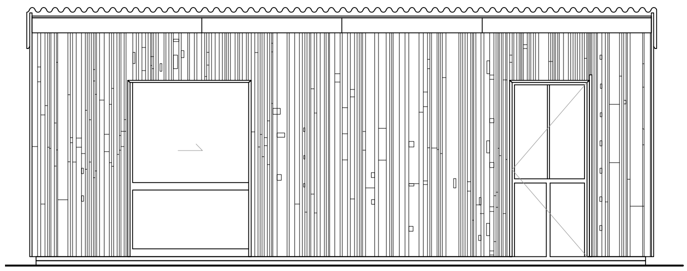
The wall of Zudaji, 403 Architecture, Hamamatsu, 2011

The project defines a warehouse for the neighbouring restaurant and is made with wooden elements. The wood comes from waste material of three previous interventions and from unusable pallets. The impermeability to water and wind is guaranteed from corrugated plastic panels anchored to the outside of the vertical closures.
The cover is made from a sheet of galvanized steel.
Wooden elements were secured with screws, thus forming both pillars and vertical partitions.

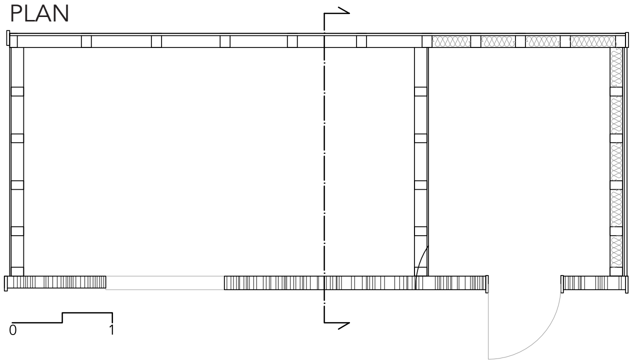
Winter temperatures:
min: 2° C
max: 9,5° C
Summer temperatures:
min: 21° C
max: 38°C

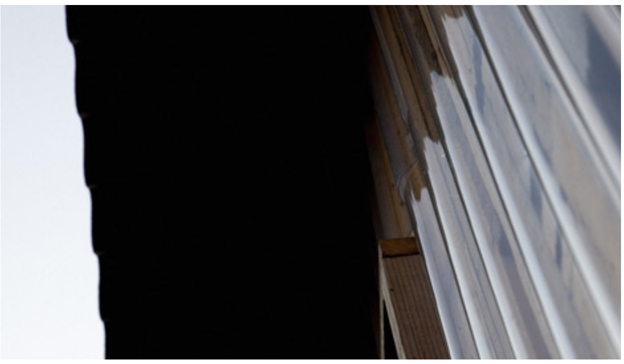


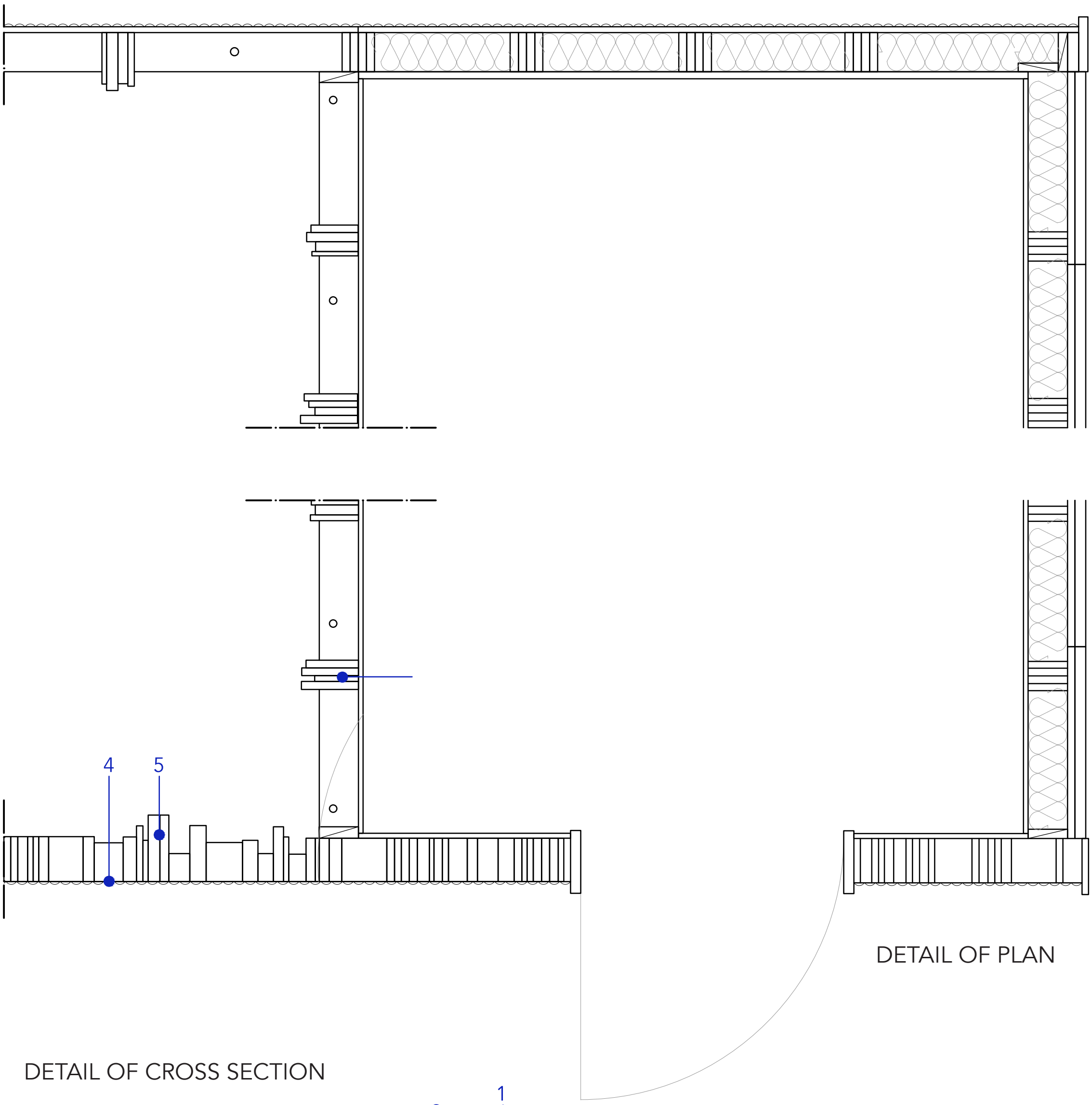
SECTION



PLAN

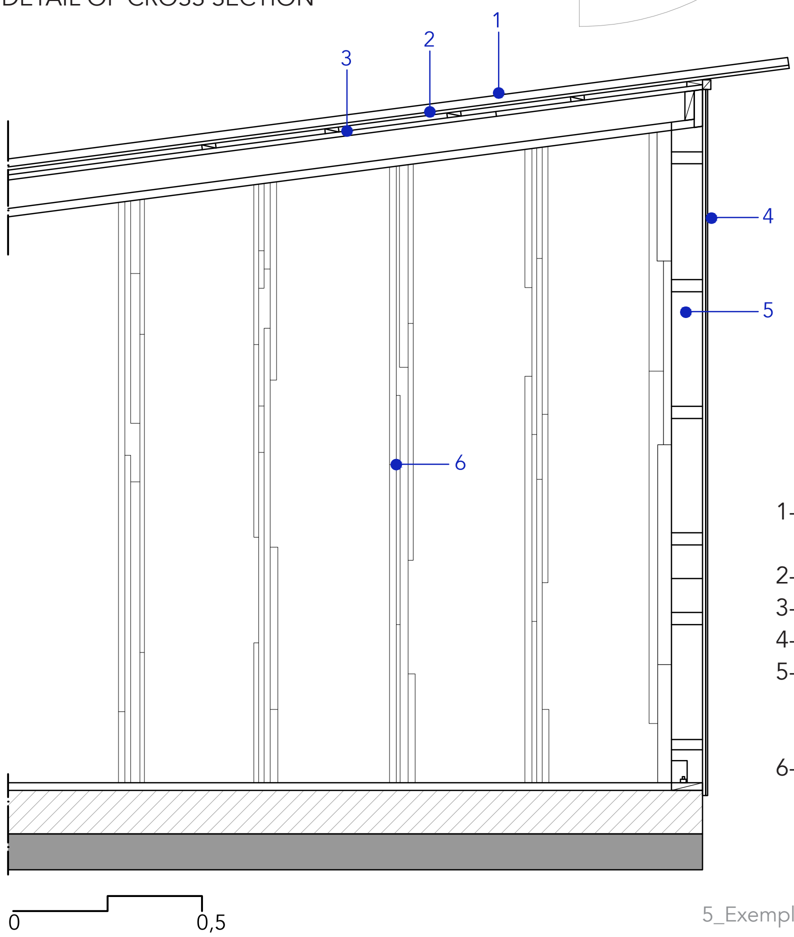






DETAIL OF PLAN

DETAIL OF CROSS SECTION



1-Corrugated sheet coated with asphalt
2-Vapour barrier
3-Structural timber, 12 mm
4-Polycarbonate panel
5-Wall made with wooden elements securely united with screws
6-Pillar (120 mm) made with wooden elements securely united with screws

Pavilion Humanidade, Juacaba, Lessa, Rio de Janeiro, 2012

The Pavilion was built with recycled multidirectional scaffolding, thanks to the type of connections. The material can be reused again.
It consists of 5 structural walls approximately 170 metres long and 20 metres high, with a distance of approximately 5.40 metres, creating paths addressed to the city.
Within a spatial grid, there are "container spaces" that host exhibition halls and conference rooms, built with wood particleboard and plywood. The bearing frame system, due to its configuration, facilitates the natural lighting and ventilation of all rooms.

Winter temperatures:
min: 21,8° C
max: 29° C
Summer temperatures:
min: 16,8° C
max: 24,8°C

Flexibility of building system:

0 10

Reversibility of building system:

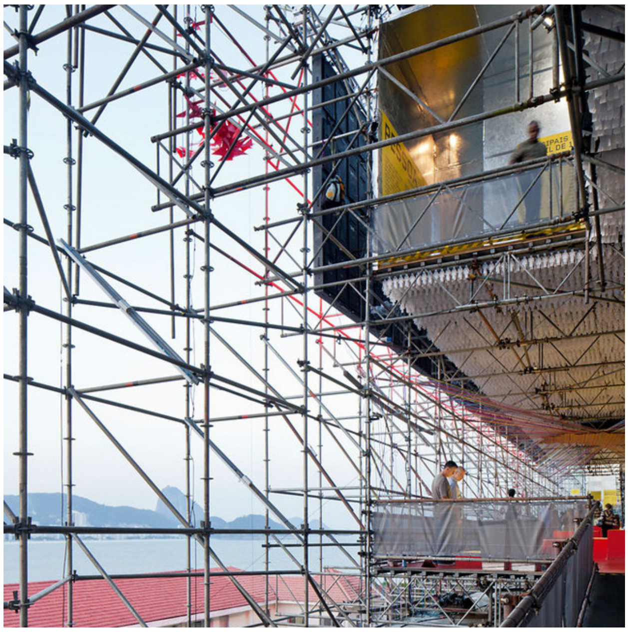
0 10

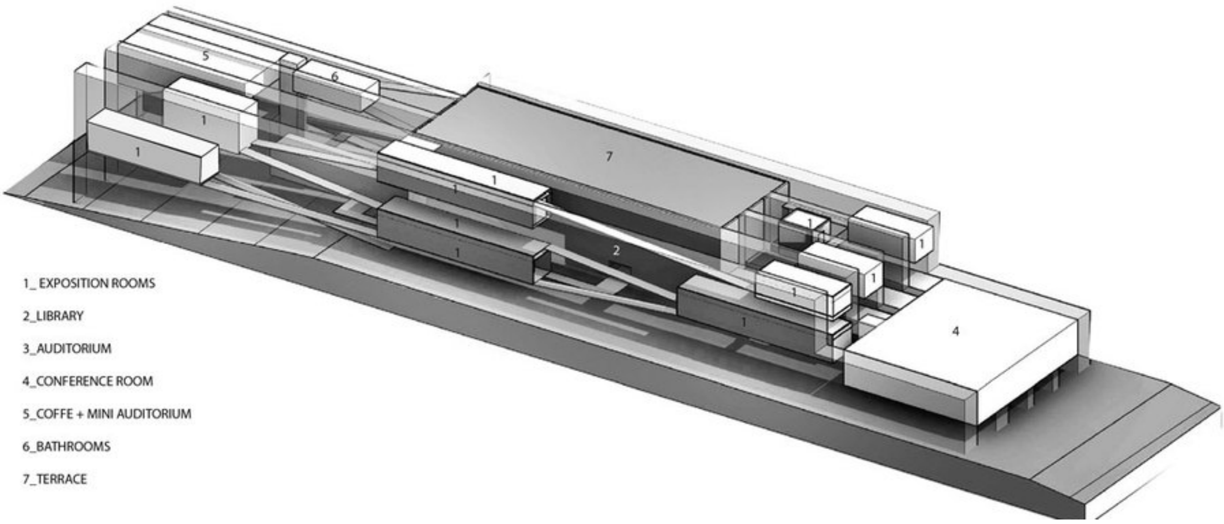
Time of assembly/disassembly:

0

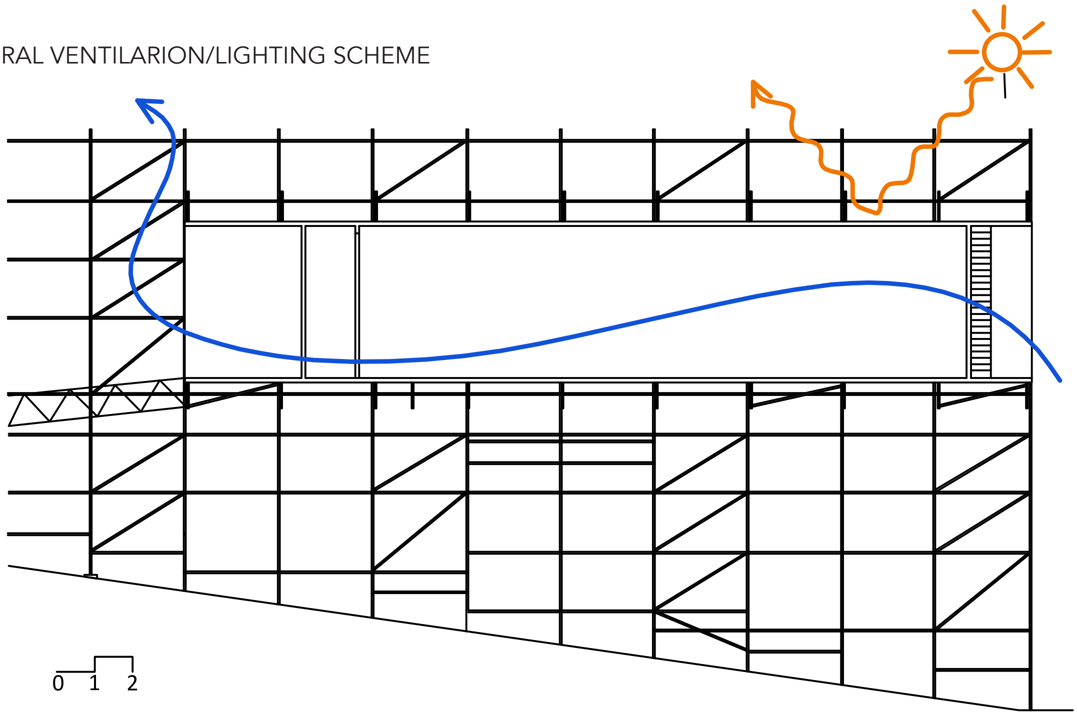
Facility of assembly/disassembly:

0 10

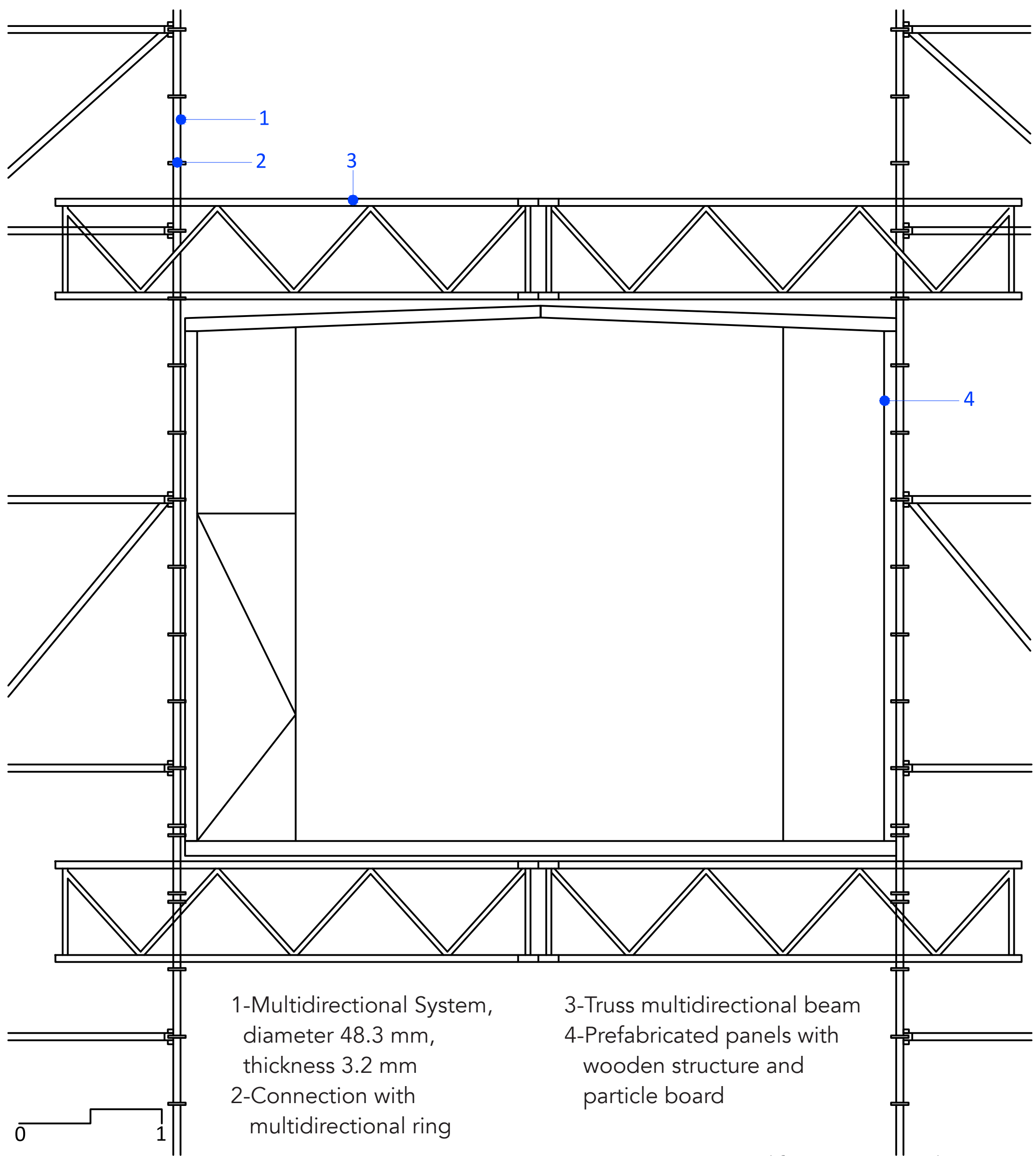




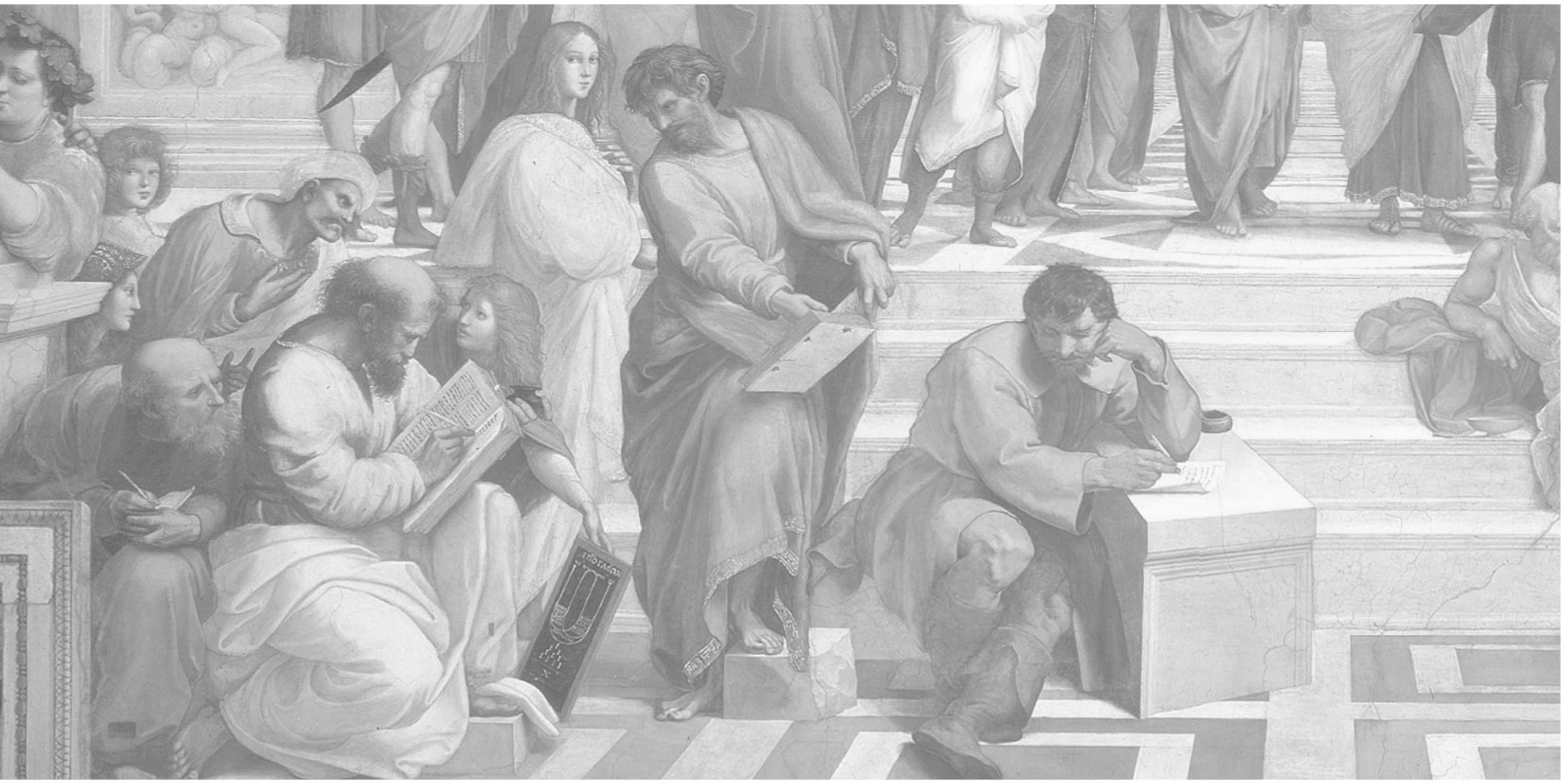
NATURAL VENTILARION/LIGHTING SCHEME



SECTION DETAIL



1-Multidirectional System, diameter 48.3 mm, thickness 3.2 mm
2-Connection with multidirectional ring
3-Truss multidirectional beam
4-Prefabricated panels with wooden structure and particle board



PHASE 4_ Research processing phase. Optimization of the reuse of materials resulting from selective demolition of safety systems in L'Aquila.

The fourth phase concerns the definition of operative-methodological procedures aimed at maximizing the reuse of wood and steel, which are prevalent materials in L'Aquila's safety systems.

The research, regardless of the analysed field, follows the same logical path: the identification of the causes of degradation, health and preventive treatments and their attainable performances, the definition of re-use and the identification of good construction practices. The result of research allows the engineer to evaluate the residual performance of materials, the potential degradation in relation with environmental class and the accessible performances by treatments. If these parameters are implemented into the system, we can identify the potential modes of reuse to optimize the durability and maximize the characteristics of the element at the same time. The potential modes of reuse should then be compared with actual reuse in a specific territory and in a limited time.

For the structural use of wood, experimental laboratory tests are made, which aim to identify the suitability of the visual grading method and the attribution of values established by the legislation for the elements that have already undergone a life cycle. On the basis of the results, combined with the international legislation, a specific grading process is proposed for used wooden elements, without prejudice to security, which takes into account the information arising from the first lifecycle in order to exploit the real performance of the element and not those suppositories. This method guarantees the environmental sustainability of the process of reuse.

In the non-structural wood system, the method detects how to optimize the durability depending on the species and the climatic conditions in which they are placed.Even in this case, the knowledge of correspondence of the element to boundary conditions in first life cycle provides useful information for reuse.

In the field of steel elements, the isotropy of material allows for the definition of a more straightforward reuse process, based on current international standards.

The information retrieved from the first life cycle and the type of treatment performed and carried out allow the design of maintenance plans to prevent degradation, conditioned by the reuse mode (structural or not) and the corrosiveness of the environment.

6 _ WOODEN ELEMENTS: OPTIMIZATION OF REUSE

6.1 _ The durability of the wood

The durability of wood is strongly influenced by the deterioration which it undergoes, as a function of the boundary conditions of its cycle of life (type of use, temperature, humidity, accidental events etc.). The degradation therefore can be from one or more of the following:

1. physical:
- fire causing its combustion and hence, destruction;
- elements that do not compromise the under layers, causing cosmetic surface discoloration and an alteration of the structure and of the surface layers: solar rays (UV) that activate a chemical process of oxidation of the wood that is turning grey surface (aging by photolysis); rain sliding on the wood that penetrates in the cracks creating a wetland which over time leads to rot in the wood; more generally the water and the humidity have a crucial role in the preservation of the wood by keeping it hydrated, but when in direct contact or by thermo-osmosis, they can cause areas of moisture and consequently, rot;
- lesions and cracks that cause changes in mechanical properties, which can be caused by traumatic events (lightning, shock, etc.) that produce a discontinuity in the woody tissue, by alternating the balance of internal tensions that are released in the fresh timber immediately after harvesting or volumetric shrinkage of wood when the humidity falls below the point of saturation (about 30% in the wood anhydrous). The most common values for the withdrawal of fresh wood are between 0.2-0.5 % axially, between 3-9 % radially, between 7-19% in a tangential direction[1], therefore, they shall run in the direction of the grain of the wood following its indentations and irregularities; also, during the drying, tensions are created which cause deformations as well as distortions, buckles, cracks and shrinkage cracks;

2. chemical: when it is attached by basic products due to its acidic nature;
3. biological: when it is attacked by mushrooms and insects that feed on organic substances which constitute the wood;
- vegetal attack: the fungi are aerobic organisms and are called "parasites" when they settle on living plants and "saprophytes" when they settle on cut down plants, they are divided in:
  - dry rot fungi: generally, these attack the wood when the humidity is higher than the 20%, feed on cell wall components of wood, they attack both sapwood and heartwood; there are brown rot fungi that mainly attach the cellulose, giving a brown colour, generate longitudinal and lateral cracks (aspect like cubes), and make the wood brittle; the white rot fungi, which attack the cellulose and the lignin, give a white and fibrous aspect; the soft rot fungi give a dark colour and look, at first wet and subsequently dry as the wood undergoes consequent hardening and cracking;
  - staining fungi: these require a high humidity (>30%), feed on the substances present in the sapwood (starch, proteins, and sugars) and do not attack the cell wall of the wood and cause an alteration of the colour without causing structural damages; a good example is the blue staining fungi (give a grey-blue colour);
  - imperfect fungi: these are surface molds that do not penetrate the wood, but remain on surface; examples include Aspergillus, Penicillum, and Trichoderma;
- animal attack: the presence of wood boring insects is recognisable by the presence of holes; the beetles (Anobiids, Bostrichidae, Cerambycidae, Lycidae, Platypodidae, Scolytidae and Curculionidae) the isoptera (Rinotermitidae, Kalotermitidae) and the hymenoptera (Siricidae, Formicidae) are the orders of insects that attack the cut down wood; they dig tunnels in the

wood causing loss of mechanical strength; the same insects attack the fresh wood and others the seasoned wood[2], in reference to the latter case it is possible to distinguish:

- anobiids ("woodworm"): insects of cylindrical shape of 2-9 mm, with brown colour, whitish larvae penetrate the wood, digging tunnels and, once adults, the insects emerge from circular holes with diameter from 1 to 3 mm, their attack only being visible outside when the holes begin to appear, i.e. when the insects are already adults and the wood is severely compromised; the time for this process is variable, between 2 and 3 years;
- cerambycidae ("capricorn beetles"): insects of 1-2 cm with brown colour, the female lays her eggs in the crevices of the wood and the larvae dig tunnels to the heartwood to become adults and leave the holes. The timing for that process is variable between 4 and 8 years, creating holes are oval with a diameter from 5 to 10 mm;
- curculionidae: insects of 3-5 mm with a brown colour with rostrum, both the larvae and the adults dig tunnels with a diameter less than 1 mm and come from the oval hole;
- rinotermitidae and kalotermitidae ("termites"): winged insects that base their organisation on three castes: the reproductive cast can be active (king and queen) and potential, the soldiers (ochre colour) have the task of defending the colony from predators and workers (white colour) are sterile and take care of the operation of the colony. The subterranean termites also attack wood up to tens of meters from the nest. Otherwise, the dry wood termites have their nest inside the wood and expel their excrement through holes on the surface of the wood.

The correlation between the agents of degradation, effects, consequences and damages is made explicit in the following table[3]:

Agents	Effects	Consequences	Damages
Fire	Fire	Burning	Destruction of the wood
Sun- short wave UV radiation	Photochemical attack of the wood Depolymerisation of the cellulose	Discoloration (yellowing, browning) Possible increase of the absorption capacity of the surface Attack of staining and lichen fungi	
Sun- short wave UV radiation and temperature change	Swings of temperature and humidity Drying caused by the reduction of the humidity Size variation due to swelling and shrinkage Mechanical solicitation	Discoloration (yellowing, browning) Formation of fissures and cracks Possible increase of humidity Biological attack	Rot Decrease of structural characteristics Destruction of the wood
Wind	Erosion Aging of the sealant	Lack of tightness, mild cracks	
Rain Humidity of the soil and/or of the air	Increased of moisture Size variation due to swelling and shrinkage Thermo-osmosis	Discoloration (yellowing, browning) Formation of fissures and cracks Biological attack	Rot Decrease of structural characteristics Destruction of the wood
Internal tensions	Rebalancing of the tensions	Formation of fissures and cracks	Decrease of structural characteristics
Basic products	Chemical reaction	Discoloration (yellowing, browning) Weakening	Destruction of the wood

The humidity of the air conditions, as seen previously, the risk of the development of fungi, in particular, the European standard[4] identifies five classes that relate the type of use with the risk of attack (larger is the class, greater is the risk):

- class 1: situation where the wood or the wood-based product is repaired, fully protected from the elements, and not exposed to moisture;
- class 2: situation where the wood or the wood product is repaired and fully protected from the elements, but where high environmental humidity can determine an occasional humidification event but is not persistent;
- class 3: situation where the wood or the wood product is not repaired and is not in contact with the ground; it is continually exposed to atmospheric agents or, while being protected against atmospheric agents, is subject to frequent wetting;
- class 4: situation where the wood or the wood product is in contact with the ground and with fresh water and it is therefore permanently exposed to humidification;
- class 5: situation where the wood or the wood product is permanently exposed to salt water.

Therefore, the wood used in safety systems belongs primarily to class 3 and sometimes to class 4.
Such classes of use correspond to the service class n.3, in accordance with the European standard EN 1995-1-1 "Design of timber structure- Part.1-1: General- Common rules and rules for buildings."
Concerning attacks by fungi, in function of the risk class and durability the standard[5] defines the need of preserving treatments, as reported in the below table (Fig.1).
The possibility of application of a treatment both in cases of attack by fungi and insects is closely correlated with the impregnability of the wooden element in the sapwood and in the heartwood, i.e. with facility of penetration of the treatments and of the water within the wooden element. In particular the standard6 defines the following classes of impregnability:

1. impregnable: easy to impregnate; the lumber can be penetrated completely, without difficulty by pressure treatment;
2. moderately impregnable: enough easy to impregnate; normally it is not possible a complete penetration but with a pressure treatment of 2 or 3 hours it can be achieve a lateral penetration of 6 mm in conifers and a of large proportion of the vessels in broad leafs;
3. slightly impregnable: difficult to impregnate, a pressure treatment for 3 or 4 hours allows a lateral penetration between 3 mm and 6 mm;
4. not impregnable: virtually impossible to impregnate, poor quantity of preserving absorbed even after 3-4 hours of pressure impregnation; minimum lateral and longitudinal penetration.

While in risk class 1 the possibility of insects attack is primary, due to the low level of humidity that is detrimental to the survival of fungi, risk classes 2, 3, 4 and 5 the possibility of fungi attach is of primary concern. Therefore, the choice of species and eventual treatments must be considered as well as the geographic localisation and the prevalent risks of biological attack. Each species is more suitable for a specific purpose, both for dimensional characteristics of the stem and for the material characteristics of wood (durability, impregnability of heartwood and sapwood).
In function of the natural durability of wood specie to the

Classe di rischio	Classe di durabilità				
	1	2	3	4	5
1	0	0	0	0	0
2	0	0	0	(0)	(0)
3	0	0	(0)	(0) - (x)	(0) - (x)
4	0	(0)	(x)	x	x
5	0	(x)	(x)	x	x

Legenda:
0 durabilità naturale sufficiente,
(0) la durabilità naturale è generalmente sufficiente, ma per certi utilizzi finali può essere raccomandato un trattamento preservante (vedere appendice A),
(0) - (x) la durabilità naturale può essere sufficiente, ma in funzione della specie legnosa, della sua permeabilità (vedere 6.1) e del suo utilizzo finale (vedere appendice A), può essere necessario un trattamento preservante,
(x) il trattamento preservante è normalmente raccomandato, ma per certi utilizzi finali la durabilità naturale può essere sufficiente (vedere appendice A),
x trattamento preservante necessario.

Nota *L'alburno di tutte le specie legnose dovrebbe essere considerato come appartenente alla classe 5 di durabilità.*

Fig. 1 _Wood boring fungi- Classes of durability of wood species for the use according to the risk classes.
UNI EN 460:1996 "Durabilità del legno e dei prodotti a base di legno. Durabilità naturale del legno massiccio. Guida ai requisiti di durabilità per legno da utilizzare nelle classi di rischio"

attack of fungi and insects mainly located in the place of installation and of the impregnability of the heartwood and sapwood, it is possible locate the treatments required and the maximum use class in which the element can be used. For each species, the classes of durability and impregnability can be defined.

The table below (Fig.2) shows the data for the main imported species of wood in Europe. It is important to know the specific resistance of a wood species compared to the attack of certain species of insects, as some species only damage the sapwood while other attack both sapwood and heartwood.

Comparing to the type of insects predominantly present in the area of installation to the natural durability of wood according to the specific present attack and to the impregnability of the most stressed part (sapwood, heartwood, or both), it is possible evaluate the possibility of reuse of the wooden element.

The fir (white and red) is not resistant to fungi, anobiids, capricorn beetles, and termites. Firs are, however, resistant to lycidae. Firs have moderate permeability in the sapwood and low permeability in the heartwood.

The larch is little to moderately resistant to fungi attack, but it is not resistant to anobiids, capricorn beetles and termites, while it is resistant to lycidae. It presents a low permeability in the sapwood and no permeability in the heartwood.

The pine (scots and black) presents a sapwood that is not resistant to fungi, anobiids, Capricorn beetles and termites, but it is resistant to lycidae. The heartwood is moderately resistant to fungi and termites and resistant to anobiids, capricorn beetles and lycidae. Pine presents a high permeability in the sapwood and zero permeability in the heartwood. Otherwise, the above-mentioned species have comparable characteristics. The chestnut is durable to fungi attack and it is resistant to Hylotrupes bajulus and not resistant to Hesperophanes cinereus, anobiids, capricorn beetles and termites. Chestnut presents a moderate impregnability in the sapwood and no permeability in the heartwood.

Specie			**Durabilità naturale**						**Impregnabilità**	
Nome commerciale	**Nome scientifico**	**Origine**	**Funghi**	**Insetti**						
				Hyl.	**Hesp.**	**An.**	**Ly.**	**Term.**	**D**	**A**
Abete bianco	*Abies alba* Mill.	EU, USA	4	NR	R	NR	R	NR	2-3	2
Abete rosso	*Picea abies* L. Karst.	EU	4	NR	R	NR	R	NR	3-4	3
Douglasia	*Pseudotsuga menziesii* (Mirb)	USA	3	NR	R	NR	R	NR	4	3
Larice	*Larix decidua* Mill.	EU	3-4	NR	R	NR	R	NR	4	2
Pino silvestre	*Pinus sylvestris* L.	EU	3-4	NR	R	NR	R	NR	3-4	1
Castagno	*Castanea sativa* Mill.	EU	2	R	NR	NR	NR	NR	4	2
Pioppo	*Populus* spp.	EU	5	R	NR	NR	R	NR	3	1
Querce caducifoglie	*Quercus* spp	EU	2-4	R	NR	NR	NR	NR	4	1

Classi di durabilità naturale ai funghi
1 – molto durabile
2 - durabile
3 – moderatamente durabile
4 – poco durabile
5 – non durabile
Insetti del legno
Hyl. – Hylutrupes bajulus
Hesp. – Hesperoohanes cinereus
An. – Anobidi spp.
Ly. – Lyctus spp.
Term. – Termite spp.

Classi di impregnabilità del legno: A (alburno), D (durame)
1 – impregnabile
2 – moderatamente impregnabile
3 – poco impregnabile
4 – non impregnabile
Classi di durabilità naturale agli insetti isotteri o termiti
R – resistente
MR – moderatamente resistente
NR – non resistente
Classi di durabilità naturale agli insetti coleotteri
R – resistente
NR – non resistente

Fig. 2 _Natural classes of durability to fungi and insects and classes of impregnability with respect to the specie.
UNI EN 350-2:1996 "Durabilità del legno e dei prodotti a base di legno. Durabilità naturale del legno massiccio. Guida alla durabilità naturale e trattabilità di specie legnose scelte di importazione in Europa."

6.2 _ The treatments for the wood

The treatments for the wood are divided into:

- preventive: when applied to healthy wood before it is used to prevent it being attacked by wood boring organisms;
- curative: when they are applied on wood that has already been attacked by wood-boring organisms.

In cases of reuse of wood that has already lived a life cycle, it is necessary, once performing an analysis on the type of present degradation, to make curative treatments in order to eliminate the factors that caused the deterioration and lowering of performance.

The application of curative treatments is necessary only in cases in which the wood element has undergone a lowering of the structural characteristics or in cases in which degradation phenomena are in place that will decrease performance over time. In cases in which, instead, the wood has suffered discoloration (due to stiffening or fungi) that have caused aesthetic damage, for the purpose of reuse, curative treatments are not necessary.

Then, once the causes of degradation are arrested, before putting back in place the wooden elements, it is necessary evaluate, if necessary, the application of preventive treatments, with the aim that the wood does not suffer a further reduction of its performance.

The aim of the preventive treatment is to provide to the wood durable characteristics similar to naturally durable wood.

The choice of the type of the treatment to be carried out depends on various factors:

- the condition of deterioration of the element and the possible presence of active attacks;
- the use or the reuse that it is intended;
- the impregnability of the element object of the treatment;
- the efficacy of the treatment;
- the timing and the costs of the application;
- theenvironmental impact of the treatment.

The wooden treatments through chemical means are:

- water-borne preservatives: these are consist of a mixture of inorganic salts dissolved in water. In Europe, copper chrome arsenic (CCA) is widely used. CCA reacts in contact with the wood and give rise to insoluble compounds, allowing to the wood a greater durability even when it is used outside. In addition to CCA, the preservatives of this type most used are the following: chromated zinc chloride (CZC), ammonium copper arsenate (ACA), acid copper chromate (ACC), chrome copper boron (CBC), ammonia copper zinc arsenate (ACZA), inorganic borates and quaternary ammonium salts;
- oil vehicle preservatives: these are mixture which are derived from the distillation of tar from coal at a temperature comprised between 200 °C and 400 °C; thanks to this oily nature these are water repellent and reduce the chances of cracks and deformation of wood and are typically used for external applications and, in cases of contact with the ground (cross members of rails, buried poles, earthworks, etc.), the preservatives of this type most frequently used are the creosote and oil of tar;
- curatives/ preservatives in an organic medium: these are made by fungicidal and/or insecticidal substances dissolved in solvents such as diesel, kerosene, solvent naphtha, etc; the active substance most commonly used is copper naphthenate; zinc naphthenate, pentachlorophenol, and tributyl tin oxide are also used.

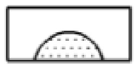
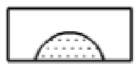
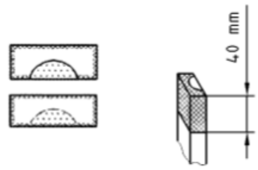
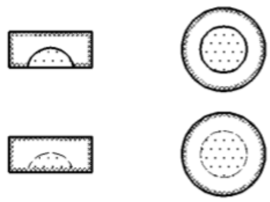
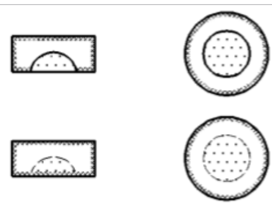
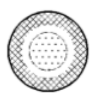
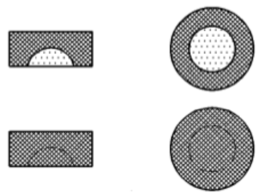
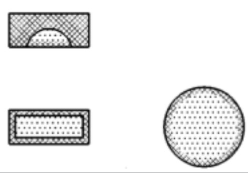
The curatives/preservatives made of chemical products can be applied:

- pressure in plant (autoclave): ensures a high/medium penetration of the preservative in the wood and is applied to the wood which will be used in the risk classes 3, 4 and 5; the methods most used are:
  - impregnation with pressure: after the wooden elements are hermetically sealed, a preservative liquid is introduced into the autoclave at a pressure variable between 7 and 14 bar, which is maintained for a variable period from 1 to 6 hours; the full-cell process (o Bethell) consists of applying a depression of air into the autoclave, before the insertion of the liquid, differently the empty-cell process (o Rueping), consists of applying a compression of air into the autoclave before the insertion of the liquid;
  - low pressure: after the wood elements are hermetically sealed into the autoclave, the preservative liquid is introduced with a variable pressure between 0,7 and 1,3 bar through a cushion of compressed air in the upper part of the autoclave which is maintained for a variable period between 1-4 hours;
  - double vacuum: the autoclave, after the wood was added, is subjected to a vacuum and it is filled with the preservative, thereafter the autoclave is reported to the atmospheric pressure that acts by pushing the preserving agent inside the wood;
- pressure in site and in plant:
  - curative piloted injections: holes are drilled (3 to 5 holes per meter) with a depth equal to about 2/3 the thickness of the element; nozzles equipped with non-return valves are inserted into the holes through which the curative is forced with pressure;
- without pressure in site and in plant:
  - fumigation: a curative action, the wooden elements are exposed to toxic gases for a variable time, up to 24 hours and the fumes penetrate deep into the wood in order to eliminate the larvae and are often hydro reactive products;
  - immersion: the wood is immersed in a tank containing the curative/preservative, in function of the time (variable from a few hours to several days) and of the degradation of the impregnability;
  - roller, brush and spry: the wood element is brushed or sprayed with curative/preservative products using machinery in the plant and by hand on site;
  - rain or fog: the element is sprayed with curative/preservative products in a special room, in plant or by hand on site.

Each product presents according to the legislation (Euro-

pean legislation EN 351-1:2006), a penetration class (NP1-NP2-NP3-NP4- NP5-NP6-), that expresses a requisite of penetration, in function of the wooden species and the class of use. Such reactions are shown in the below table.
Wood treatments can also occur through physical means as:

- thermo-curative treatment through microwaves: based on selective or differential heating of the materials according to their dialectical characteristics; the oscillating magnetic field generated by the microwaves drive the water molecules to move quickly, their friction generating heat, devitalizing biological infested forms constituted of water (about 15%); it used a frequency of oscillation of 2450 MHZ, raising of the outside temperature about 55-65 °C and, consequently, inside about 100-140 °C applied for 30-60 minutes[7], guarantees the destruction of biological organisms. It can be performed both in reverberant rooms (i.e., enclose spaces where they are placed), and on site through portable machines;
- thermo-curative treatment by heater air: the wooden elements are placed in isolated rooms, or wrapped in thermal insulation if the operation is made on site, and hot air is blown with the purpose of heating the wood and reaching mortal temperatures for the biotic organisms. In this type of operation, it is appropriate to adequately control the temperature in order to avoid thermal stress of the wood and to control the loss of relative humidity by controlled humidification, especially when working on wooden elements that already have evident cracks, in order to avoid their increase.

Class of use	Wooden species	Class of penetration	Requirement of penetration	Schematic illustration
1	All	NP1	absent	
2	All	NP1	absent	
3	Resistant	NP2	3 mm of sapwood on the lateral faces and 40 mm of sapwood in axial direction	
	Permeable[8]	NP3	6 mm of sapwoof on lateral faces	
4	Resistant	NP3	3 mm of sapwoof on lateral faces	
	Permeable	NP4 (legno tondo)	25 mm of sapwood	
		NP5	All the sapwood	
5	Permeable	NP6	All the sapwood and minimum 6 mm oh hardwood	

At preventive level, in addition to applying with pressure or chemical products, it is possible to make also additional treatments in the plant that have a less impact on the environment and that have the aim to change the wood structure in some characteristics with the purpose of increasing the durability. Between these:

- thermo treatment: the wood undergoes a thermal process that leads to a temperature between 160 and 240 °C, with consequent chemical modification of the components of the cell wall, with improvement of the characteristics in terms of dimensional stability, increase of durability, but worsening in terms of strength and flection;
- oleothermic treatment: the wood is soaked in vegetable oils at temperature of about 160 °C, becoming hydrophobic and thereby limiting the dimensional stability and the shrinkage cracks while simultaneously preserving the timber from leaching tannins.

It drew up a summary table that divide the treatments in preventive (TP) and curative (TC), specifying their applicability in plant (S) or on site (C).

Treatments	TP	TC	S	C
Impregnation with pressure full cell process	X		X	
Impregnation with pressure empty cell process	X		X	
Low pressure impregnation	X		X	
Double vacuum impregnation	X		X	
Immersion	X	X	X	X
Roller, brush and spry	X	X	X	X
Rain or fog	X	X	X	X
Piloted injections		X		X
Fumigation		X	X	X
Thermo treatment through microwaves		X	X	X
Thermo treatment by heater air		X	X	X
Thermo treatment	X		X	
Oleothermic treatment	X		X	

In the reuse of the wooden elements of the safety systems, it is convenient to favour the operations of reconditioning that take place on site in order to speed the reconstruction operations. Notwithstanding attention to the environmental impact of treatment, it then proceeds to a further specification of the same, in terms of operative mode, describing the individual stages in terms of efficacy, analysis, and of the advantages and disadvantages. These assessments allow to the companies, or to the Public Administration that deals with the removal and subsequent reuse, of identifying, in function of the phenomena of degradation in place, the workers, and available tools, execution times and processing costs, the more efficient treatment, in order to enhance the effective potentials of the reuse of the individual elements.

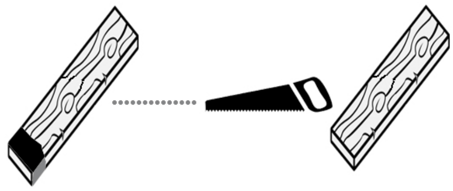
Treatment with immersion	Preventive/curative
Operating modes: • Wire brushing and scraping • Preparation tank with curative/preservative product • Immersion of elements (variable time: a few hours/a few days) • Drying	Effectiveness: • 3/6 mm of impregnation Disadvantages: • Use of chemical products • Effectiveness only for adult insects • Difficult realization in sites in case of large elements Advantages: • low-middle costs
Treatment with roller, brush, spray, rain or fog	**Preventive/curative**
Operating modes: • Wire brushing and scraping • Treatment by hand with roller, brush, spry, fog • Drying	Effectiveness: • Impregnation of all zones with biological attack Disadvantages: • Use of chemical products • Effectiveness only for adult insects Advantages: • Low costs
Treatment with pilot injections	**Curative**
Operating modes: • Pickling • Wire brushing and scraping • Drilling with holes (3/5 holes for each meter) • Insertion of nozzles • Injection by pressure of liquid • External treatment with spry	Effectiveness: • Impregnation of all zones with biological attack Disadvantages: • Use of chemical products Advantages: • Middle costs • Effectiveness for all type of biological attack
Treatment with fumigation	**Curative**
Operating modes: • Wire brushing and scraping • Predisposition of hermetic area • Removal of people and animals • Activation of the fumigant product • Elapsed the time needed, ventilation area	Effectiveness: • 6 mm of impregnation Disadvantages: • Use of chemical products • High environmental pollution Advantages: • Low costs • Effectiveness for all type of biological attack

Thermal microwaves	Curative
Operating modes: • Use of acoustic detector for the presence of organisms • Preparation equipment • Emission of oscillation frequency of 2450 MHZ • Treatment for about 60 minutes and monitoring through electronic control (succession of about 30 minutes of surface each 15 minutes) • Dismantling equipment	Effectiveness: • Total action Disadvantages: • Possible danger for humans (it is necessary to operate in conditions of extreme safety) • Long time of application Advantages: • High cost • It do not alter the wood • Effectiveness for all types of biological attack
Thermal with hot air	**Curative**
Operating modes: • Preparation of thermally insulated area • Preparation of machinery of insufflation and control instrumentation (temperature / humidity) • Insufflation hot air • Controlled humidification • Dismantling machinery	Effectiveness: • Total action Disadvantages: • Average time of application • Potential damage to wood Advantages: • Middle costs • Effectiveness for all type of biological attack

The class of use gives the optimal use of both a kind and mode of preventive treatment. Otherwise, the chance of a curative treatment depends on the intensity and on the position of the biological attack. When the attack is serious and the wood has already lost its characteristics of minimum resistance considered necessary for a non- structural use, it should proceed to the removal of the deteriorated part. When the deteriorated part is closest to the cylinder head, it is appropriate to proceed to the cut while minimising the impact on the length of the element. When instead, the attack of a severe form is in intermediate parts of the attack, the removing of the diseased part will result in a substantial reduction in the length of the element, which will be divided into more, smaller elements.
Otherwise, when there is an attack in mild form, depending on the environmental, economic and logistic convenience and depending on the characteristics of the wooden element, it will be necessary to assess the opportunity of a curative treatment or to eliminate only the superficial part, reducing the section of the element. The opportunity of such intervention also occurs when the wooden element is subject to a spread attack of biological elements (such as cerambycidae) that act predominantly on the outside part.

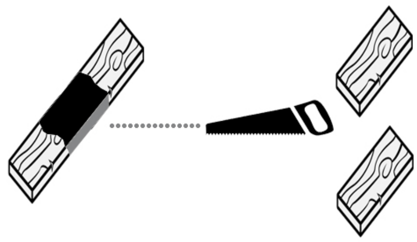
POSSIBLE OPERATING MODES IN THE EVENT OF BIOLOGICAL ATTACK

Severe attack at the head



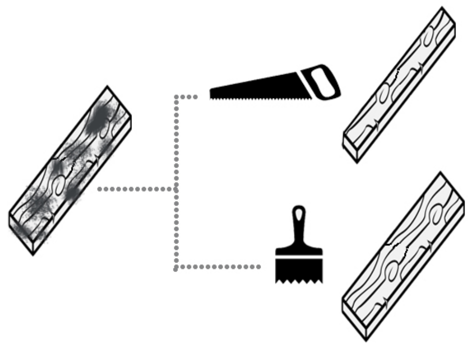
1) Cut of the diseased part with reduction of length.

Severe attack intermediate



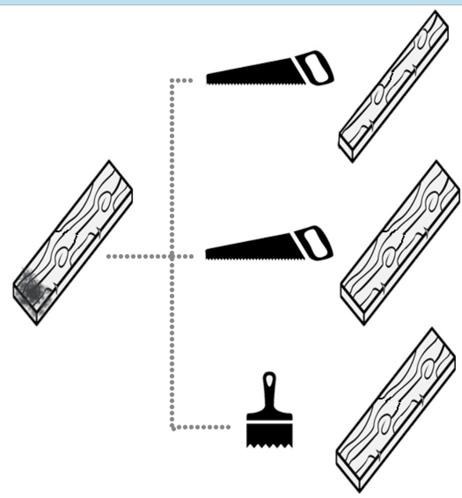
1) Cut of the diseased part with reduction of length and division into two or more elements

Spread and surface attack.



1) Surface removal of the diseased part with reduction of the section
2) Curative treatment

Surface attack at the head



1) Surface removal of the diseased part, with reduction of the section
2) Cut of the diseased part with reduction of length
3) Curative treatment

6.3 _ Analysis of elements in wood arising from selective demolition

Purposes of the analysis

The analysis carried out and below further detailed according to wooden elements that have already suffered a life cycle, present two main objectives:

1. to assess the correspondence between the characteristic values defined by visual grading and values defined by experimental analysis, especially for that which concerns the volumetric mass, the modulus of elasticity and the bending strength, from which it is possible to extract the derived values;
2. to compare the correspondence between the visual grading and the mechanical characteristics of new elements with the correspondence of the same grading with the mechanical characteristics of used elements, to assess the similarities and the divergences.

The evaluations will define the possibilities to reuse the wooden elements to structural use or non-structural roles and to assess the application of the process of specific classification for the used elements suitable to increase the safety of reuse and at the same time to ensure environmental sustainability.

Method and mode of analysis

The wooden elements used for the analysis, defined below in detail, derive from selective demolitions made in the Valencian Community. The use of elements that derive from demolitions has allowed the investigation of residual performances of wooden beams that have already had a lifecycle up to 50 years. In fact, although it is not possible to estimate precisely the age of wooden elements, they mainly constituted the beams of decks with vaults in brick, according to a constructive system typically used in the Valencian Community[9] up to about 1920s. There is, however, the use of such a system in the 1960s, because of the unavailability of construction materials aside from wood due to the Civil War.

The constructive system provides for the use of wooden beams that, thanks to other nailed wooden elements, support brick vaults that constitute formworks for filling concrete; in the bottom a system of braided ropes is prepared by nailing, holding up a braided which acts as a false ceiling. The analysis are carried out on championed massive beams in wood pine with cross section of 17.50 x 5.8 cm and of variable length. In the case of softwood, especially in the case of used elements, that in the majority of cases show signs of deterioration, it is very difficult to determine the species only through visual analysis because the silver fir and some pine species may look the same to the eye. Therefore, to define precisely the species of the elements in the interests of proper mechanical characterisation were performed by microscopic analysis[10].

Thanks to the use of dichotomous keys, it has been possible to identify the membership of the wood to the following family: *Pinus sylvestris* L., *Pinus nigra* Arnold, *Pinus mugo* Turra. These species have, anatomically, indistinguishable features, but it is possible to distinguish the presence of elements of *Pinus mugo* Turra due to the limited length of the logs and the consequent lack of application in construction, while *Pinus sylvestris* L. e il *Pinus nigra* Arnold present similar mechanical features[11].

In L'Aquila, for safety, they have used mainly wood elements of softwood (pine and white fir) in large part for the fact that they are economically advantageous and, only in

Fig. 3 _Constructive system, tipical in Valencian Community

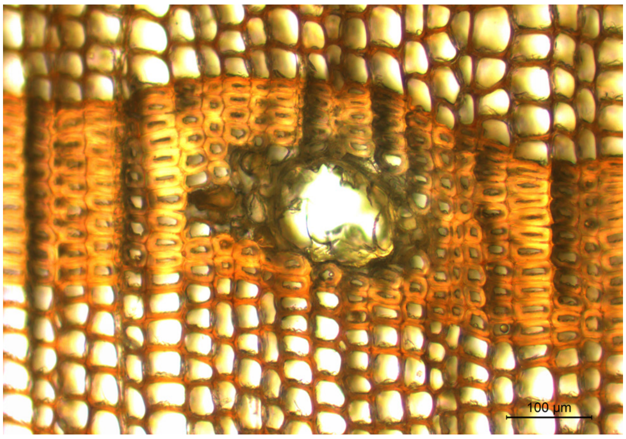


Fig. 4 _Transversal view- element n.8

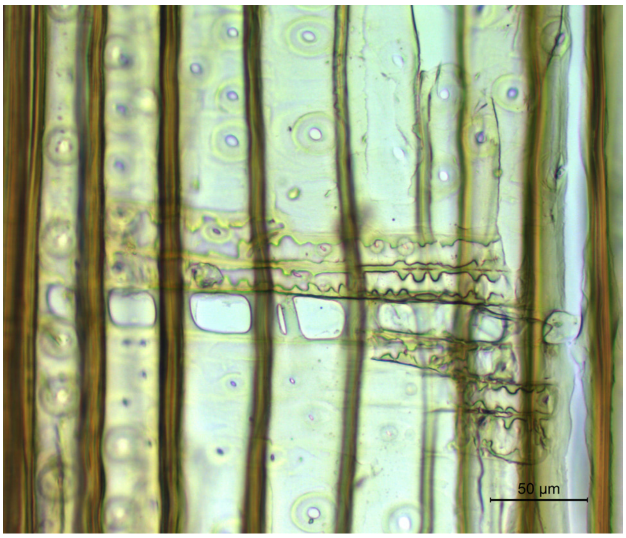


Fig. 5 _Radial view - element n.8

limited cases, in the wood of more expensive broad leaf species. From the analysis carried out in the laboratory on pine elements (*Pinus sylvetris* L. , *Pinus nigra* Arnold), it will be possible through comparative method to perform similar considerations also on other species, with the aim to define a process of valid procedures, regardless of the species. The used elements for the analysis present a lifecycle well above that currently in progress for the constituent elements of the safety systems, which allows the assumption of realistic scenarios for the future. It should be noted that, although the analysed elements have lived most of their lives in closed environmental conditions (having the functions of beams); in recent years they have been stored at the outdoor storage areas of the demolition enterprise and exposed to external atmospheric conditions. Therefore, their use for the defining of residual performances of wood elements represents a protective condition in reference to the safety elements used in L'Aquila.

The analyses have followed the procedure below described. First step was the visual classification of the wooden elements that establishes a relationship between the characteristics, defects and resistant properties, identifying the critical point causing a lowering of the mechanical characteristics and assuming the possible modes of failure as a function of the applied load. This correlation has the aim to define the class of a resistant element useful for the structural calculation, ensuring, however, a cautionary assessment of the actual resistant properties.

The eligibility of a useful element for the structural use with rectangular section must be verified as described in European Standard EN 14081- 1:2005+A1:2011 "Timber structures. Strength graded structural timber with rectangular cross section. Part 1: General requirements." In compliance with the resistant classes as established by the European Standard EN 338:2009 "Structural Timber. Strength Classes," and with the European Standard EN 1310:1997 "Round and sawn timber. Method of measurement of features," for the method of evaluation of the characteristics of the element (knots, wane, slope of grain, fissures, etc.). The European Standard is specified by national regulations in relation to the prevalent species and construction and techniques of processing. In Italy, the visual grading of solid wood can be made by the Standard UNI 11035:2010 "Legno strutturale. Classificazione a vista dei legnami secondo la resistenza meccanica." (Structural wood. Classification in view of the timber according to mechanical strength.) or with the Standard UNI 11119:2004 "Beni culturali. Manufatti lignei. Strutture portanti degli edifici. Ispezione in situ per la diagnosi degli elementi in opera." (Cultureal heritage. Wooden artifacts. Bearing structures of buildings. Inspection in situ for the diagnosis of the elements in work.) The fundamental difference consists in the form of the obtained results. The Standard UNI 11035 can be applied to both the new wood and in work, provided they are satisfied the visual conditions of almost 3 faces and 1 head, in the classification that is made in reference to the worst defect and are determined classes of resistant profiles that define characteristic values of the element (S1-S2-S3). Otherwise, the Standard UNI 11119 can be applied in all cases of inspection "in situ" and refers to the concept of the "critical zone", providing categories of resistant profile in terms of allowable stress and average values of flexural elastic modulus (I-II-III).

It should be emphasized that the NTC 2008[12] enable the verification method of the allowable stress only for the construction of type 1 and 2 and use class I and II, limited to locations that fall in Zone 4; therefore, it is more convenient for the purposes of a subsequent structural verification the use of the UNI 11035. In addition, in the case of wood, that constitutes the safety system, in most cases, 3 faces and both heads are visible or in any case, after dismantling the element can be used on all sides. In the light of these considerations, it is appropriate the use of the Standard UNI 11035 for the visual grading, pointing out that this legislation relates to timber from Italy. Only if, in the reconstruction project, it is decide to maintain the wooden element in the same position in which is located in safety, (for example in case of strengthening a deck), without carrying out its dismantling and the visibility conditions of the UNI 11035 are not satisfied, it can be used the standard UNI 11119. In Spain, the visual grading of coniferous wood is carried out according to the Standard UNE 56544:2011 "Clasificación visual de la madera aserrada para uso estructural. Madera de coniferas" (Visual grading of sawn timber for structural use. Softwood.) that allows the establishment of two classes for the elements of height ≤ 70 mm (ME-1 e ME-2) and a single class for elements of height > 70 mm (MEG). Through the standard UNE EN 1912: 2005 "Madera estructural. Clases resistentes. Asignación de calidades visuales y especies." (Structural timber, strength classes, assigning visual quality and species.) it is possible to define the correspondence between the visual classes and resistant classes in function of wood species. The parameters taken into account for visual grading are described below.

- Measurement of the element: length, width, and height. The width and the height were measured at the ends and in the centre lines.
- Rate of growth: measurement on the heads of the average length of the growth rings, drawing a perpendicular segment to the some; in the classification according to the standard UNE 56544, the first five rings from a distance of 25 mm from the pith (as presents) are considered and in the classification according to the standard UNI 10035, it was considered a breadth of 75 mm.
- Knots: in case of classification according to the standard UNE 56544, the diameter of the knots has been measured in a perpendicular direction to the length of the element. The knots with a smaller diameter of 10 mm have not been take into account, with the exception of knots that pass on the another face. In case of a corner knot, the measurement was carried out on the side where it is most unfavourable in relation between dimensions of the knot measured in perpendicular direction to the length of the element and to the width of the facade, they were considered as groups of knots. The knots whose centres are less than 150 mm apart or when the grain does not recover the original direction (in this case the distance between

the knots is insignificant) are considered a single knot as per the classification standard UNI 10035, but knots with a diameter less than 5 mm were ignored. It was considered the largest knot of the lumber and calculated the relationship between its minimum diameter and the width of the facade on which such diameter is considered. In cases of groups of knots, the sum of minimum diameters of knots comprised in a stretch of 150 mm and the width of the facade on which they appear was considered.

- Slope of grain: it was determined on the basis of the visible shrinkage cracks, measuring the projection in horizontal and in vertical.
- Fissures: the type of present fissures (shrinkage cracks, lightning cracks, frost cracks or cracks) were identified and only the fissures with a greater length to the smaller size between 1/4 of the length and 1 meters were taken into account. In this case, the evaluation was performed by dividing the maximum depth for the length.
- Ring shakes: the type of ring shakes have been detected and has been measured the radius and the eccentricity.
- Wanes: they have the length measured, the central point with respect to the reference axis and the projection size of the wanes on both sides, the report has been calculated between the difference of size of the side without wanes and the side with wanes and the dimension of the side without wanes.
- Resin pockets: the dimension in parallel direction to the length of the element was measured.
- Deformations: bow, crook, twist, and cup were measured, and the measurement has been carried to the extremes of the element.
- Degradation: evaluation of the presence of physical, chemical and biological degradation with an indication of exact position of the type of degradation and description of their characteristics.

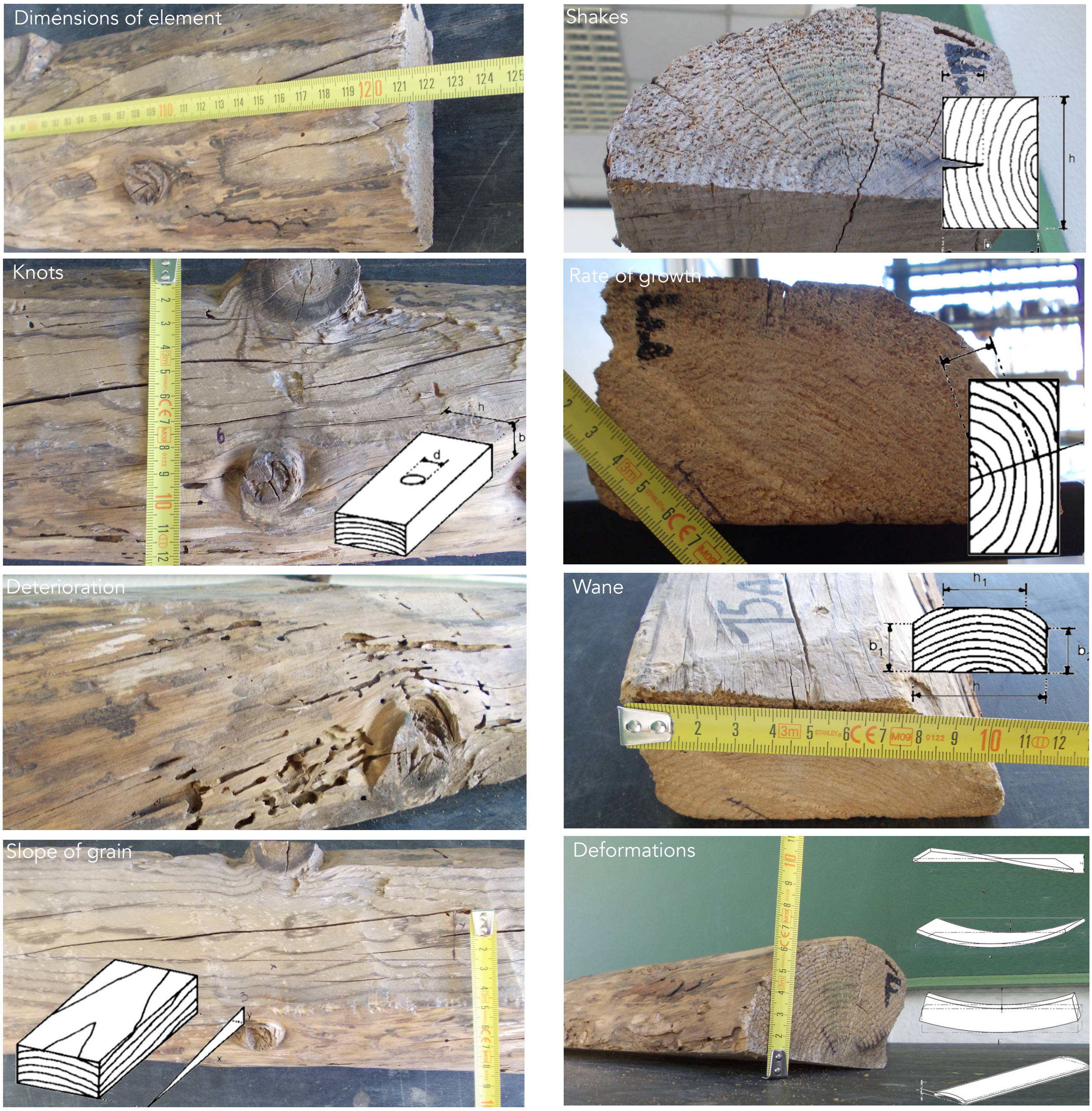


Fig. 6 _ Main parameters considered in visual grading

UNI 11035-2 (Italia)

Table 2 - Indicates the classification criteria valid for: Abete bianco (Abies Alba Mill), Abete rosso (Picea Abies Karst.), Larice (Larix Decidua Mill.), Pino Silano (Pinus nigra J.F., Pinus laricio), Pino Silvestre (Pinus Sylvestris), Pino nero (Pinus Nigra Arn.), Pino marittimo (Pinus Pinaster Sol.), Pino domestico (Pinus pinea L.), Pino strobo (Pinus strobus).

"Conifere 1"			
Criteri per la classificazione	Categorie		
	S1	S2	S3
Smussi[1)]	$s \leq 1/4$	$s \leq 1/3$	$s \leq 1/3$
Nodi singoli[2)] Nodi raggruppati[3)]	$A \leq 1/5$ e comunque d <50 mm $A_g \leq 2/5$	$A \leq 2/5$ e comunque d <70 mm $A_g \leq 2/3$	$A \leq 3/5$ $A_g \leq 3/4$
Ampiezza anelli	≤6 mm	≤15 mm	
Inclinazione fibratura	≤1:14 (7,0%)	≤1:8 (12,5%)	≤1:6 (16,5%)
Fessurazioni: - da ritiro - cipollatura - da fulmine, gelo, lesioni	 ammesse, se non passanti non ammessa non ammesse	 ammesse. Se passanti con limitazioni[6)] ammessa con limitazioni[4)] non ammesse	
Degrado da funghi: - azzurramento - carie bruna e bianca	 ammesso non ammesse		
Legno di compressione	fino a 1/5 del perimetro sulle facce o della sezione	fino a 2/5 del perimetro sulle facce o della sezione	fino a 3/5 del perimetro sulle facce o della sezione
Attacchi di insetti	non ammessi	ammessi con limitazioni[5)]	
Vischio	non ammesso		
Deformazioni: - arcuatura - falcatura - svergolamento - imbarcamento	 10 mm ogni 2 m di lunghezza 8 mm ogni 2 m di lunghezza 1 mm ogni 25 mm di lunghezza nessuna restrizione		 20 mm ogni 2 m di lunghezza 12 mm ogni 2 m di lunghezza 2 mm ogni 25 mm di larghezza nessuna restrizione

1) s è espresso come rapporto tra la proiezione dello stesso smusso su una superficie e la larghezza totale di questa superficie.

2) Si considera il nodo più grande del segato, e il rapporto A fra il suo diametro minimo d e la larghezza della faccia su cui tale diametro viene misurato.

3) Non considerare questo criterio per Abete e Larice/Nord Italia. Per le altre combinazioni specie/provenienza considerare il rapporto A_g fra la somma dei diametri minimi dei nodi compresi in un tratto di 150 mm e la larghezza della faccia su cui compaiono.

4) Generalmente non ammessa; soltanto per Larice/Nord Italia e Abete/Italia la cipollatura visibile o probabile è ammessa se $r_{max} < b/3$ ed $\varepsilon < b/6$,
dove:
r_{max} il raggio massimo della cipollatura;
b il lato maggiore della sezione;
ε l'eccentricità, cioè la distanza massima del midollo rispetto al centro geometrico della sezione.

5) Ammessi solo fori con alone nerastro, oppure fori rotondi, senza alone nerastro, di diametro compreso tra 1.5 e 2.5 mm (di Anobidi), purché l'attacco sia sicuramente esaurito, per un max. di 10 fori, distribuiti uniformemente, per metro di lunghezza (somma di tutte e quattro le facce).

6) Fessurazioni passanti ammesse solo alle estremità, per una lunghezza non maggiore della larghezza del segato.

Table 5- Characteristic values for type of timber. For timber constituent systems safety can be used the columns: “Abete/ Italia” and “Altre conifere/Italia.”

Proprietà		Abete/Italia			Pino laricio/Italia			Larice/Nord Italia			Douglasia/Italia		Altre conifere/Italia			Castagno/Italia	Querce caducifoglie/Italia	Pioppo e Ontano/Italia	Altre latifoglie/Italia
Corrispondenza con le Classi di resistenza della UNI EN 338			C24	C18	C40	C22	C14		C22	C18	C35	C22				D24			
Categorie resistenti		S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2/S3	S1	S2	S3	S	S	S	S
Flessione (5-percentile), N/mm^2	$f_{m,k}$		25	18	40	22	15		23	18	35	22	33	26	22	28	42	26	27
Trazione parallela alla fibratura (5-percentile), N/mm^2	$f_{t,0,k}$		15	11	24	13	9		14	11	21	13	20	16	13	17	25	16	16
Trazione perpendicolare alla fibratura (5-percentile), N/mm^2	$f_{t,90,k}$		0,4	0,4	0,4	0,4	0,4		0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,6	0,6	0,6	0,6
Compressione parallela alla fibratura (5-percentile), N/mm^2	$f_{c,0,k}$		21	18	26	20	17		20	18	25	20	24	22	20	22	27	22	22
Compressione perpendicolare alla fibratura (5-percentile), N/mm^2	$f_{c,90,k}$		2,6	2,6	3,2	3,0	3,0		3,6	3,6	3,2	2,9	3,7	3,7	3,7	7,3	11	6,3	7,7
Taglio (5-percentile), N/mm^2	$f_{v,k}$		4,0	3,4	4,0	3,8	3,0		3,8	3,4	4,0	3,8	4,0	4,0	3,8	4,0	4,0	2,7	4,0
Modulo di elasticità parallelo alla fibratura (medio), kN/mm^2	$E_{0,mean}$		11,8	10,5	15	12	11		12,5	11,5	15,8	13	12,3	11,4	10,5	12,5	12,0	8,0	11,5
Modulo di elasticità parallelo alla fibratura (5-percentile), kN/mm^2	$E_{0,05}$		7,9	7,0	10	8,0	7,4		8,4	7,7	11	8,7	8,2	7,6	7,0	10,5	10,1	6,7	9,7
Modulo di elasticità perpendicolare alla fibratura (medio), kN/mm^2	$E_{90,mean}$		0,39	0,35	0,50	0,40	0,37		0,42	0,38	0,53	0,43	0,41	0,38	0,35	0,83	0,80	0,53	0,77
Modulo di taglio (medio), kN/mm^2	G_{mean}		0,74	0,66	0,94	0,75	0,69		0,78	0,72	0,99	0,81	0,77	0,71	0,66	0,78	0,75	0,50	0,72
Massa volumica (5-percentile), kg/m^3	ρ_k		375	375	455	425	430		510	520	450	415	530	530	530	485	760	420	515
Massa volumica (media), kg/m^3	ρ_{mean}		450	450	550	520	520		610	620	540	500	575	575	575	580	825	460	560

UNE 56544 (Spagna)

Table 2- Specifications for the visual grading of elements of wood with height ≤70 mm.

CRITERIOS DE CALIDAD	**ME-1**	**ME-2**
DIÁMETRO DE LOS NUDOS SOBRE LA CARA (h)	d ≤ 1/5 de "h"	d ≤ 1/2 de "h"
DIÁMETRO DE LOS NUDOS SOBRE EL CANTO (b)	d ≤ 1/2 de "b" y d ≤ 30 mm	d ≤ 2/3 de "b"
ANCHURA MÁXIMA DEL ANILLO DE CRECIMIENTO (1) – Pino silvestre – Pino laricio – Pino gallego y pinaster – Pino insigne (radiata)	 ≤ 4 mm ≤ 5 mm ≤ 8 mm ≤ 10 mm	 Sin limitación Sin limitación Sin limitación Sin limitación
FENDAS – De secado (2) (3)	f ≤ 2/5	f ≤ 3/5
	Las fendas de secado sólo se consideran si su longitud es mayor que la menor de las dimensiones siguientes: 1/4 de la longitud de la pieza y 1 m.	
FENDAS – Rayo – Heladura – Abatimiento	No permitidas	
ACEBOLLADURAS	No permitidas	
BOLSAS DE RESINA y ENTRECASCO	Se admiten si su longitud es menor o igual que 1,5·"h"	
MADERA DE COMPRESIÓN	Admisible en 1/5 de la sección o de la superficie externa de la pieza	Admisible en 2/5 de la sección o de la superficie externa de la pieza
DESVIACIÓN DE LA FIBRA	1:10 (10%)	1:6 (16,7%)
GEMAS – longitud – dimensión relativa	 ≤ 1/4 de "L" g ≤ 1/4	 ≤ 1/3 de "L" g ≤ 1/3
MÉDULA (1)	Admitida No admitida si se clasifica en húmedo	Admitida
ALTERACIONES BIOLÓGICAS – Muérdago (*V. album*) – Azulado – Pudrición – Galerías de insectos xilófagos	 – No se admite – Se admite – No se admite – No se admiten	
DEFORMACIONES MÁXIMAS (2) (3) (4) – Curvatura de cara – Curvatura de canto – Alabeo – Abarquillado	 10 mm (para una longitud de 2 m) 8 mm (para una longitud de 2 m) 1 mm (por cada 25 mm de "h") (para una longitud de 2 m) sin limitación	 20 mm (para una longitud de 2 m) 12 mm (para una longitud de 2 m) 2 mm (por cada 25 mm de "h") (para una longitud de 2 m) sin limitación

(1) Estos criterios sólo se consideran cuando se comercializa en húmedo.
(2) Estos criterios no se consideran cuando la clasificación se efectúa en húmedo.
(3) Referidas a un 20% de contenido de humedad.
(4) Pueden aceptarse deformaciones mayores siempre que no afecten a la estabilidad de la construcción (porque puedan corregirse durante la fase del montaje) y exista acuerdo expreso al respecto entre el suministrador y el cliente.

Table 3- Specifications for the visual grading of elements of wood with height >70 mm.

CRITERIOS DE CALIDAD		MEG
DIÁMETRO DE LOS NUDOS SOBRE LA CARA (h)		d ≤ 2/3 de "h"
DIÁMETRO DE LOS NUDOS SOBRE EL CANTO (b)		d ≤ 2/3 de "b"
ANCHURA MÁXIMA DEL ANILLO DE CRECIMIENTO (1) – Pino silvestre – Pino laricio – Pino gallego y pinaster – Pino insigne (radiata)		 Sin limitación Sin limitación Sin limitación Sin limitación
FENDAS	De secado (2) (3)	f ≤ 3/5 Las fendas de contracción sólo se consideran si su longitud es mayor que la menor de las dimensiones siguientes: 1/4 de la longitud de la pieza y 1 m.
	– Rayo – Heladura – Abatimiento	No permitidas
ACEBOLLADURAS		No permitidas
BOLSAS DE RESINA y ENTRECASCO		Se admiten si su longitud es menor o igual que 1,5·"h"
MADERA DE COMPRESIÓN		Admisible en 2/5 de la sección o de la superficie externa de la pieza
DESVIACIÓN DE LA FIBRA		1:6 (16,7%)
GEMAS – longitud – dimensión relativa		 ≤ 1/3 de "L" g ≤ 1/3
MÉDULA (1)		Admitida
ALTERACIONES BIOLÓGICAS – Muérdago (*V. album*) – Azulado – Pudrición – Galerías de insectos xilófagos		 – No se admite – Se admite – No se admite – No se admiten
DEFORMACIONES MÁXIMAS (2) (3) (4) (5) – Curvatura de cara – Curvatura de canto – Alabeo – Abarquillado		 20 (10) mm (para una longitud de 2 m) 12 (8) mm (para una longitud de 2 m) 2 (1) mm (por cada 25 mm de "h") (para una longitud de 2 m) sin limitación

(1) Estos criterios sólo se consideran cuando se comercializa en húmedo.
(2) Estos criterios no se consideran cuando la clasificación se efectúa en húmedo.
(3) Referidas a un 20% de contenido de humedad.
(4) Pueden aceptarse deformaciones mayores siempre que no afecten a la estabilidad de la construcción (porque puedan corregirse durante la fase del montaje) y exista acuerdo expreso al respecto entre el suministrador y el cliente.
(5) Se toman los valores más exigentes indicados entre paréntesis, cuando la calidad MEG de lugar a una clase resistente superior a C18.

UNE EN 1912 (Spagna)

Relation between the visual grading and the resistance class

Pine laricio	ME-1	C30	ME-2	C18	MEG	C22
Pine silvestre	ME-1	C27	ME-2	C18	MEG	C22
Pine radiata	ME-1	C24	ME-2	C18	---	
Pine pinaster	ME-1	C24	ME-2	C18	---	

The visual grading is performed according to both standards, for rigor of analysis should be carried out only with Spanish standard, but the additional use of the Italian standard provides useful data for comparative purposes for the reuse of elements that constitute the safety systems in L'Aquila.
Also, with the aim of identifying a fail process of application of the standard, the elements with a length greater then the minimum length required for destructive tests were ranked first as unique element then divided into two parts and reclassified.
In this way, in some cases, they obtained different visual categories for elements that are derived from the division of a same beam, as reducing the length also reduces the presence of defects, which are sometimes shared evenly on two elements and sometimes, instead, they focus only on one part.
This type of analysis was carried out to simulate the reuse conditions of wooden elements which no longer have their original dimension because in their use have been cut. Think, for example, to the reuse of the elements that constitute the safety system of the openings, having generally a length of less than 1.50 m.
In addition, this type of analysis could provide useful input to evaluate the advantages to reuse a wooden element, such as how it is after the dismantling of the safety system or to evaluate the possibility of cutting a part of it in order to grow the category of the visual grading and, consequently, the resistant class.
After experimental analyses were carried out in the laboratory to identify the moisture content, volumetric mass, flexural modulus of elasticity and the bending strength from which it is possible to obtain the derived sizes. At first, it was taken to non-destructive tests and subsequently to destructive tests.
The tests, in order to define the modulus of local and global elasticity and the bending strength, were carried out according to the indications of the standard EN 408:2010 "Timber structures. Structural timber and glued laminated timber. Determination of some physical and mechanical properties." The elements were subjected to mechanical tests with the largest side parallel to the ground and with the load applied in the worst condition.
Reference lines were traced on the wooden elements, aiding in the positioning of support points and for the application of loads and sensors, locating the area of maximum load and the neutral axis. The support points of the sample were placed at a distance of 18 times the height of the element, while the load was applied over a length equal to 6 times the height and at a distance equal to 6 times the height by supports.
For the measurement of the bending modulus of elasticity, metal supports were mounted and sensors were placed such that there were two in line with the neutral axis and one below the wooden element to compute the local modulus and the global modulus, respectively. In effect, for the local modulus of elasticity we have to consider the deflection of the beam into the length of reference on the neutral axis, while for the global modulus it is important to consider the absolute deflection of the beam right in

Fig. 7 _Drawings of reference lines for the application of loads and of sensors

Fig. 8 _Monting of metal supports and positioning of sensors for the measurement of local modulus of elasticity

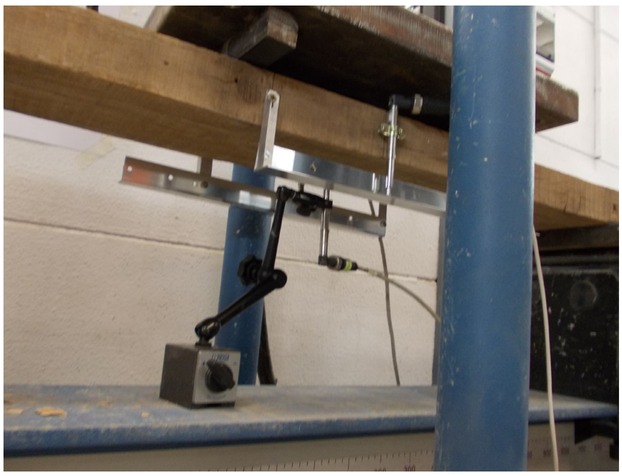


Fig. 9 _ Positioning of the sensor for the measurement of the global modulus of elasticity

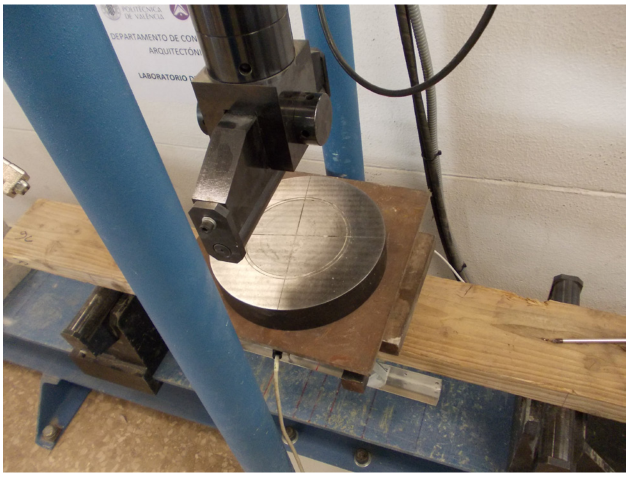


Fig. 10 _Positioning of the distribution plates for the application of the loads

Fig. 11 _Application of the load

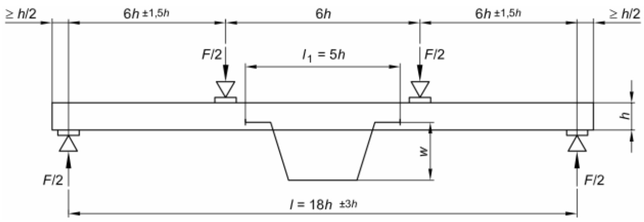
Fig. 12 _Dismantling of sensors and application of the load till break

the middle, which includes the shear deformation of the beam and any localised deformation corresponding to the supports.
After placing the element on supports, a steel plate was placed to allow sharing of the load. Afterwards, a load with a speed of 0.174 mm/s and reaching a maximum of 16 MPa was applied. A graph load/deformation was plotted and the part between 4 and 16 Mpa was used. A correlation coefficient of 0.99 or greater was detected and the modulus of elasticity was calculated using the formulas below.

Local modulus of elasticity:

$E_{m,l} = (a l_1^{2}(F_2 - F_1))/ (6 I (w_2 - w_1))$

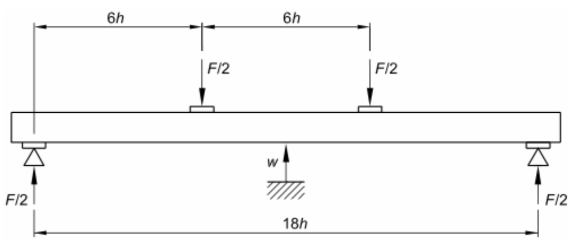
where:
a: distance between a loading position and the nearest support (mm)
l_1 : gauge length to determine the modulus of elasticity (mm)
I: the moment of inertia (mm^4)
F_2 - F_1 : increment of the load on the straight line portion of the load deformation curve (N),
w_2 - w_1: increment of deformation corresponding to F2-F1 (mm)



Global modulus of elasticity:

$E_{m,g}= (3al^2-4a^3)/(2bh^3*(2*((w_2 - w_1)/(F_2 - F_1))-(6a/5Gbh)))$

where:
a: distance between a loading position and the nearest support (mm)
b: width of the cross section (mm)
h: depth of cross section (mm)
l: bending length (mm)
G: shear modulus, equal to 650 N/mm2
F_2 - F_1 : increment of the load on the straight line portion of the load deformation curve with a correlation coefficient equal to 0,99 (N)
w_2 - w_1 : increment of the deformation corresponding to F2-F1 (mm)

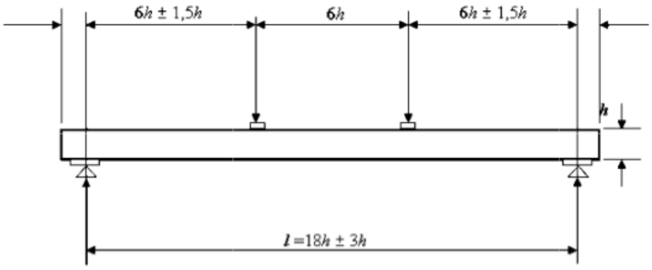


Subsequently, the sensors were removed and the flexion test was performed. The support and load points remained unchanged, but the load was applied at a constant speed to achieve the maximum load within 300 ± 120 seconds. The bending strength was calculated using the formula:

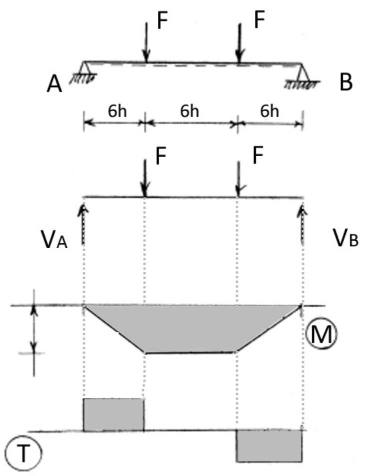
Bending strength:

$f_m = a\ F_{max}/(2W)$

where:
a: distance between a loading position and the nearest support (mm)
F_{max} : maximum load (N)
W : section resistance modulus (mm^3)



The flexural behaviour of the timber was therefore investigated, considering the static scheme of a supported beam.



The next step was the calculation of the media volumetric mass, calculated as the reaction between the mass and the volume of a sample element, determining both values with the some moisture of the element. For the measurement, they used precision instruments. Later, it was decided to calculate the reference moisture according to the indications present in the standard EN 13183-1:2002, "Moisture content of a piece of sawn timber. Determination by oven dry method."
The moisture, in fact, influences both durability and mechanical characteristics of the timber.
The mechanical tests for the determination of the characteristics are carried out by taking the reference values for moisture (65% ±5%) and for the temperature (20° ±2°)

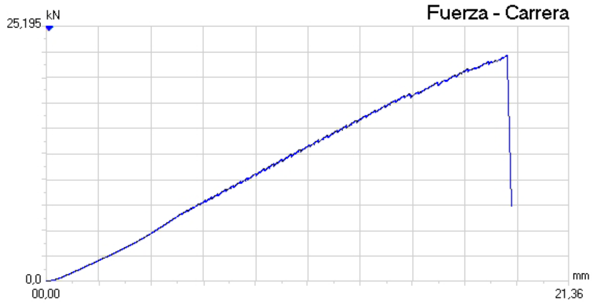


Fig. 13 _Diagram force-displacement, element n.8

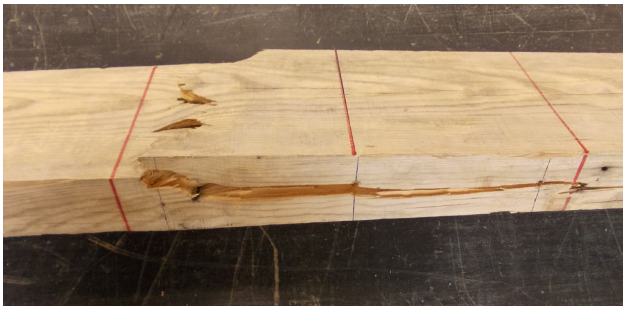


Fig. 14 _Structural failure of element n.8, view from above

Fig. 15 _Structural failure of element n.8, view frontal

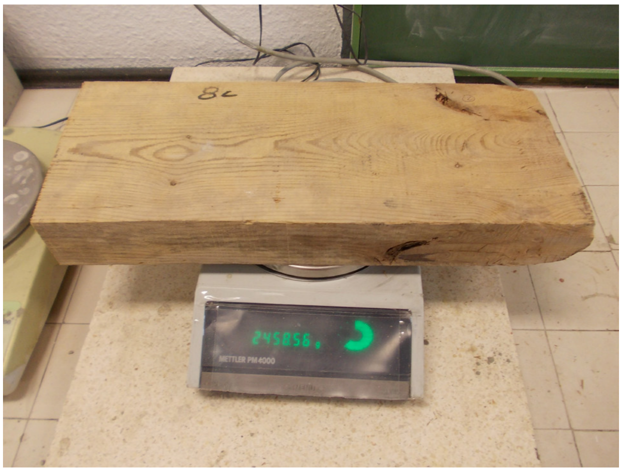


Fig. 16 _Measurement of the mass of a specimen for the calculation of the density

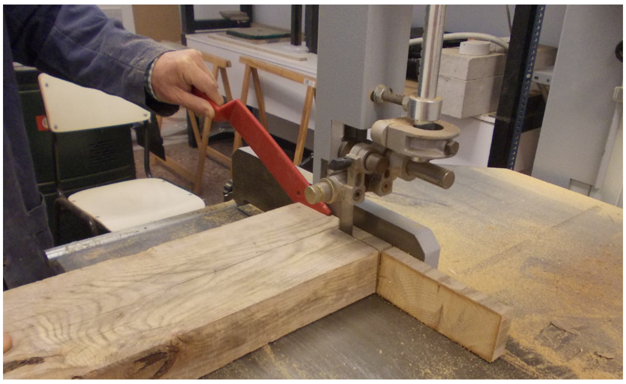


Fig. 17 _Cut of the specimens

Fig. 18 _Weighing after cutting

Fig. 19 _Drying of specimens in the oven

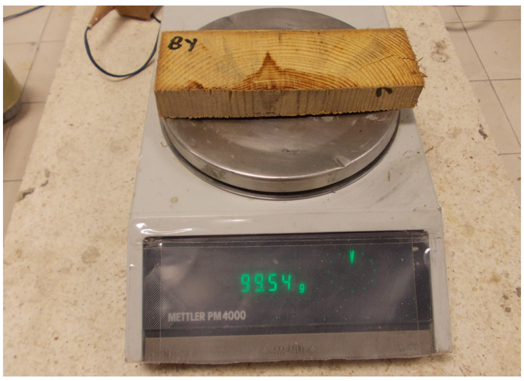


Fig. 20 _Weighing after drying

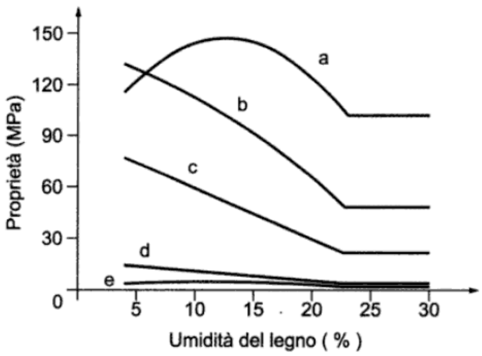
such that the humidity of the wood is equal to 12%. In fact, the wooden characteristics are strongly influenced by these two factors. Variation of humidity above the saturation point of the fibres (average value of humidity: 28%) has little influence the mechanical characteristics of the timber; otherwise, below the saturation point will highlight a strong conditioning of the properties from the moisture level, caused by the greater degree of crystallisation of the microfibers to about the European Standard EN 348:2004, "Structural timber – Determination of characteristic values of mechanical properties and density," provides variations on values calculated through mechanical tests in function of the present moisture. In particular, the elements tested whose humidity is between 8% and 18%, must be corrected to 12% humidity as follows:

- for bending strength and tensile strength; no correction is needed;
- for compression strength parallel to fibre: correction of 3% for each variation of 1% of the moisture content;
- for modulus of elasticity: correction of 1% for each variation of 1% of he moisture content;
- for compressive strength parallel to fibre and for the modulus of elasticity: the corrections have to be made so that the properties are increased, if the data are correct, to greater moisture content and vice versa.

The specimens with moisture content exceeding 18% must be corrected to a value equal to 18% and not to a value equal that real.

For most conifers the range of variation of the resistances in reference to the relation between these parameters measured in standard conditions and measured in addition to the saturation point, they are:[14]:

a) Parallel tension strength 1,1- 1,4
b) Bending strength..1,4 -2,0
c) Parallel compression strength ....1,7 -2,3
d) Perpendicular compression strength ....2,8 -3,2
e) Perpendicular tension strength...........................1,0 -1,1



For the calculation of the reference moisture, 2 layers sample of maximum cross-section and minimum size of 20 mm were obtained, by cutting in the direction of the grain at a distance of 0.3 m from one end of the piece. Immediately after cutting, the layer sample was weighed. After then layer sample was placed into the oven at a temperature of (103 ± 2) °C, until the mass difference between two successive weightings spaced of two hours was minor to 0,1%; the moisture was calculated in mass percentage as average between two sample layers.

Results and discussion.

It is shown in the following two summary tables of the results of visual classification, specifying that the non-consecutive derived from the exclusion in the process of analysis of certain elements, not congruent for species or size and that a random selection of the tested elements had brought initially to consider.

The illustrate table shows the results of the classification of the elements without having undergone cuts[13], i.e. following the selective demolition.

Element	UNI 10035-2	UNE 56544
n.1	Rejected	Rejected
n.2	Rejected	Rejected
n.3	Rejected	Rejected
n.4	Rejected	Rejected
n.5	Rejected	Rejected
n.7	S3	ME-2
n.8	S1	ME-1
n.10	Rejected	Rejected
n.11	S3	Rejected
n.12	S3	ME.2
n.13	Rejected	Rejected
n.14	Rejected	Rejected

Otherwise, the subsequent table shows the results of the visual grading obtained by dividing the wooden element (as possible) in two parts (n. A- 1 e n. A-2). It presents an improvement of the visual class and, consequently, of the alleged resistant class, when the defects which negatively condition the classification[13] are placed in one of the two parts of the element.

Element	UNI 10035-2	UNE 56544
n.1-1	S3	Rejected
n.1-2	Rejected	Rejected
n.2-1	Rejected	Rejected
n.2-2	S2	ME-2
n.3-1	Rejected	Rejected
n.3-2	S3	Rejected
n.4-1	Rejected	Rejected
n.4-2	Rejected	Rejected
n.5-1	S2	ME-2
n.5-2	Rejected	Rejected

The element n.1 considered in its entirely (length 3.0 metres) cannot be used for structural use, according to the Spanish standard, presents a group of knots, the diameter of which is greater then expected limits by the standard and a ring shakes on one of two heads and two wanes. Dividing the element in two parts (length 1.50 meters), the group of knots and one of two wanes are placed on an element (1-1), while the ring shakes and the other wanes on the other element (1-2). In the element n.1-2, is present also another group of knots with a total diameter less than that identified in the classification of the intact element, but does not return in the normative range.

Therefore, as the Spanish standard both cannot be used for a structural use; however, according to Italian standard, the wanes and the cracks affect the visual class of the element n.1, defects that in cutting operations are located on the element n.1-2. Similar considerations can be made for the elements n.3 and n.4.

According to the Spanish standard, both considered in their entirety (length 3.0 metres) and divided in two parts (length 1.50 metres), the presence of defects of different types conditioning the visual category and the widespread positioning of some, causes the non-suitability classification for structural use.

The element n.3 is discarded due to a knot and to two wanes. In division, the element 3-1 is discarded due to wanes and the element n.3-2 due to the knot. When an element presents one of more wanes, in function of the breadth of the some it is possible to evaluate the possibility of a longitudinal cutting of the element at the height of the wanes, reducing the section of the element, but, at the same, time eliminating the wanes which condition the visual category.

In the case of element n.3-1, assuming to make a longitudinal cut to eliminate the wanes, it would result in an element with length 1.50 metres with section of 12x5.8 cm, suitable, according to the visual classification, for a structural use.

Therefore, analysing the element n.3 in its entirety (17.5x 5.8x300 cm), considering the positioning of the knot that conditions the visual category, placed at a distance equal to 108 cm from one of two heads and the breadth of the wanes, by performing a transversal cut and two longitudinal cuts it is possible obtain an element with size 12x5.8x 192 cm, reusable for structural purposes.

According to the Italian standard, the element n.3, after cutting, give rise to the element n.3-2, suitable for a structural use as the wanes are ranked in the element n.3-1.

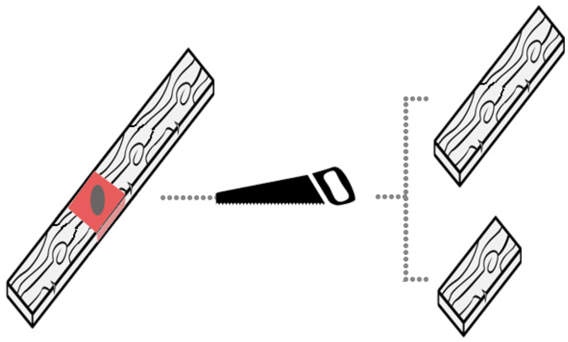
According to the Spanish standard, the element n.4 is discarded due to the presence of a group of single knots, the widespread positioning of the same which rank taking as a reference one of two heads to the distance of 55 cm, 70 cm, 100 cm and 190 cm, it prevents cutting operations to improvement the visual category since any cut would compromise the length of the element, to the point of not making it usable.

Also, according to the Italian standard, the knots negatively affect the structural reuse.

The element n.2 (length 3,0 meters) is rejected if considered in its entirety because of the presence of a group of knots and of two wanes. If it is divided in two parts (length 1.50 metres), the defects which affect the visual category are localized into the element n.2-1, while the element n.2-

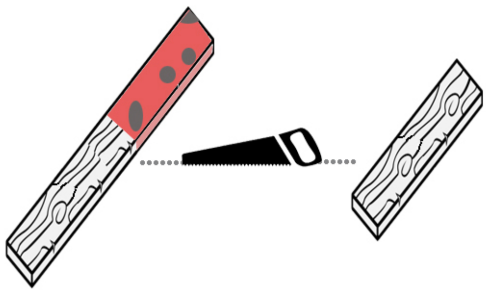
ELIMINATION OF THE WORST DEFECTS TO IMPROVE THE MECHANICAL PERFORMANCE
(when defects are knots, wanes, fissures, ring shakes or biological alterations)

Localized defects in central position



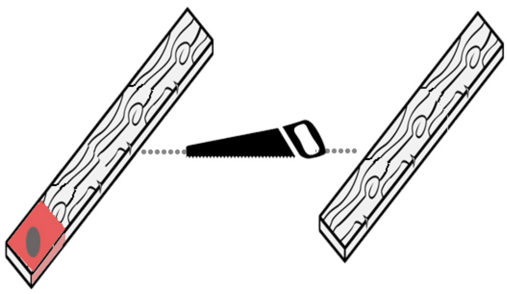
Cut of the defect in central position, two elements of lesser length are obtained.

Defects spread on one part



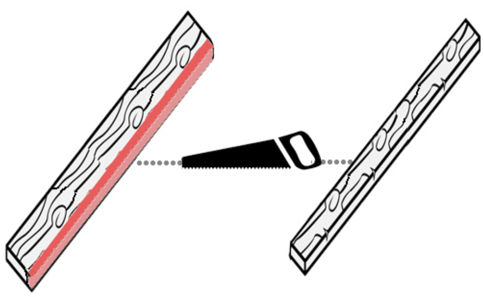
Cut of the part where many defects are present, an element of lesser length is created.

Defects located at one end



Cut of the end of the element, an element of lesser length is created.

Defects spread on one side



Cut of the side (for example wanes), an element of lower section is created.

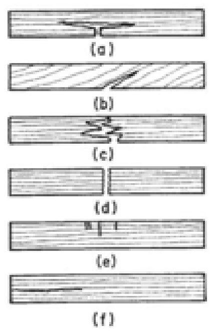
2 does not have defects that compromise his structural use and presents a visual category ME-2 for the Spanish standard and S2 for the Italian standard.
In similar way the element n.5 (length 3,0 meters) considered in its entirety is deleted because of a group of knots and a single knot. In the division (length 1.50 metres) the defects are localised only on the element n.5-2, while on element n.5-1, only defects whose parameters are returned in accordance with the structural use are present.
The analyses results indicate that in some cases the cut of a part of the element causes an increase of the visual category and, consequently, of the resistant class.
The reduction of the dimension of the element decreases, in fact, in some cases, the incidence of defects.
When the defects that affect the visual category are knots, wanes, fissures, ring shakes or biological alterations positioned in a localised way, the elimination of the part containing the defects generates an increase in performance of the part free from defects or that present minor defects.
Otherwise, when the same defects that affect the visual category are present in a widespread way or the visual category is determined by the width of rings, the slope of grain, deformation and/or by reaction wood, any cuts do not produce an improvement of the resistant class.
The cuts may be carried out with the aim of increasing the visual category of the element.
When the defects are eliminated, it is possible to use, for structural use, an element that would otherwise be discarded or to improve the visual category of an element whose defects fall within the expected range of the standard. The element n.7 presents the visual category ME-2 for the Spanish standard and S3 for the Italian standard because of the presence of knots, but also the rate of growth, any cut would not improve the visual category.
The element n.10 is discarded because of the presence of a fissure that has a length equal to 45 cm, which starts in correspondence as one of two heads.
Theoretically, the cut of the fissured par would allow the reuse of the remaining part that is free from defects such as to prevent a structural reuse.
The cut of the element for removal the fissured part would cause, however, a reduction of the length of the element to 0.80 cm, such as to decrease considerably the reuse possibility of the same.
Generally, in selective deconstruction, it is necessary to maintain the integrity of the wooden element with the aim of increasing the potential of reuse. If, however, these elements present clear defects that influence the visual category already found before disassembly, the deconstruction will also take into account the possibility to carry out cuts that speed the disassembly and at the same time do not affect the reuse of the element.
The cutting of wooden element into more parts to facilitate the operations of deconstruction can be made only when the resulting dimensions are greater or equal to 1.50 metres, i.e. they do not invalidate the potential of reuse.
Consider, for example, the disassembly of a floor, whose beams present biological degradation, the cut of the same in the degraded part will take place already in the process of demolition without affecting the reuse of elements.

The experimental analysis have produced the following results:[13]

Element n.	Density Kg/m^3	Moisture %	Local modulus of elasticity Mpa	Local modulus of elasticity (ω12%)Mpa	Global modulus of elasticity Mpa	Global modulus of elasticity (ω12%) Mpa	Bending strength Mpa
1-1	520,98	10,52	9.272,66	9.409,90	8.635,36	8.763,16	37,42
1-2	526,47	9,26	10.953,88	11.254,02	10.927,52	11.226,93	57,78
2-1	483,44	10,26	14.715,58	14.971,63	12.049,56	12.259,22	46,66
2-2	527,26	8,73	8.404,21	8.679,02	9.162,46	9.462,07	37,87
3-1	503,80	9,98	13.062,74	13.326,61	10.548,63	10.761,71	30,74
3-2	499,54	9,49	9.137,13	9.366,47	8.865,06	9.087,57	26,79
4-1	529,84	10,68	7.592,62	7.692,84	7.898,91	8.003,18	26,99
4-2	520,33	9,77	8.373,61	8.560,34	7.457,21	7.623,51	28,79
5-1	493,66	10,24	9.682,79	9.853,20	10.315,60	10.497,16	46,84
5-2	477,85	10,51	6.774,19	6.875,13	6.974,39	7.078,31	16,31
7	531,71	9,86	8.734,63	8.921,56	8.896,36	9.086,74	47,33
8	577,88	9,54	8.504,19	8.713,39	8.257,74	8.460,88	38,22
10	577,74	10,97	18.480,35	18.670,70	12.020,95	12.144,77	56,11
11	541,59	9,56	7.379,56	7.559,62	8.519,69	8.727,57	31,85
12	491,64	9,37	10.508,04	10.784,40	9.443,50	9.691,86	35,33
13	456,73	9,39	10.502,73	10.776,85	8.039,97	8.249,81	14,95
14	440,51	10,96	5.481,31	5.538,32	5.835,50	5.896,19	23,79

The inherent characteristics of the element significantly affect the flexural behaviour. In fact, an increase of the volumetric mass corresponds, generally, to an increase of the strength and stiffness of the element that grows; otherwise, increasing the water content and the deviation of the grain, decreases the resistance.
The internal knots and these in the compressed part have less influence then the external knots and these in the tensile part, it being understood the conditioning of the dimension of the knots with respect to the section of the element.
The shrinkage cracks negatively affect the flexural resistance when they are orientated vertically in areas with maximum bending moment.
In flexural deformation, the total deflection of the element was also affected by the deformability of the cut[15] and increase with increasing of the ratio between h and l.
The longitudinal fibres undergo a shift equal to the ratio between the tangential tensions and the modulus of tangential elasticity, the maximum variation of the angle between the horisontal fibres and vertical fibres is found in correspondence of the maximum tangential tensions, i.e., in neutral axis[16].
The structural failure, preceded by partial fractures (identified by acoustic phenomena), can occur by different mechanisms which may also manifest simultaneously, i.e. by traction of the fibres in the extrados, by compression in the intrados, by parallel shear to fibres on the neutral axis (rare case). In case of absence of defects, or clear wood, the structural failure may occur[17]:

- by traction (a),
- by traction in presence of deviations of the fibers (b),
- in splintered way in case of low water content (c),
- in fragile way in case of abnormal molecular structure (d),
- by compression (e)
- by shear (f).



In the elements that were subjected to flexural testing, the breakdown occurred, in most cases, in correspondence of the zone of maximum load or middle third, where time takes on maximum value and shear is worth less.
The failure was caused, in particular, by the present knots in this area, that have had a greater influence than other defects as wanes and deformations.
From experimental analyses, it shows that about the 33% of the discarded elements (elements 1-1, 1-2, 2-1, 10), according to the visual classification it has, has resistance values greater then the minimum value (element 12), between the accepted elements for a structural use. The elements 1-2 and 10 that among all the elements have the best values of resistance were discarded according to the

parameters of visual grading. Such consideration has a great significance also in consideration of the fact that the experimental tests were carried out in the worst condition for the element and, therefore, the resulting values are minimum values.
The limited number of the investigated elements does not allow the calculation of the characteristic strengths from experimental data and, therefore, the characteristic and average values provided by the visual grading are compared with the data obtained experimentally; they having to be higher, i.e., do not meet the values of 5th percentile, in order to prove the reliability of the visual classification made. That comparison is carried out by reference to the density, the modulus of elasticity parallel to the fibre, and to bending strength. The defined values, according to the Italian standard (UNI 11035), the values provided according to the Spanish standard (UNE 56544), and the derived values from the experimental analysis were compared (Appendix C[18]), The comparison is made considering the values of visual classification that are less precautionary: if the elements, according to visual grading, are not suitable to a structural use, it will be proven the veracity; if the elements, according to visual classification, are suitable to a structural use, it will verify that the actual values are higher than those characteristic and that these should be used in structural verification.
The Italian standard provides three categories (S1-S2-S3), independent from the height of the element, while the Spanish standard provides three categories (ME-1, -ME-2, MEG) in function of the height of the profile. Comparing the characteristic value that identifies the minor categories, the category S3 presents major values compared to category ME-2; in numbers it would, therefore, seem more cautionary than the Italian standard, whose minimum characteristic values are more elevated compared to of the minimum of the Spanish standard.
Otherwise, comparing the categories obtained from visual grading of analysed elements in any way, the Spanish standard results cautionary reuse because of the more restrictive modalities of evaluating the defects. For example, the element 1-1, 3-2 and 11 that, according to the Italian standard, present a category S3, according to the Spanish standard they are not suitable for a structural use. Therefore, although from a numerical point of view the Italian standard appears cautionary, the modality of evaluation of defects and the defined parameters makes the Spanish standard more cautionary.
We must not forget, however, that being the wood of Spanish origin, the standard UNE 56544 should present a more reliable standard, while the classification with Italian standard is only useful for comparative purposes.
For what concerns the correspondence with real values, it is observed that the Spanish standard is always precautionary. In fact, only in three cases (2-2, 7, 8) the average value of the modulus of elasticity (Eo, mean) is greater than the real value, resulting, instead of the characteristic values reported of the bending strength, the modulus of elasticity and the density and to average value of density are always lower than the real ones. The Italian standard, otherwise, is always precautionary for what concerns the bending strength and the characteristic modulus of elasticity, while it is always not cautionary for what concerns the average modulus of elasticity (Eo, mean) and the average and characteristic density (ρmean). Such cases are, by reporting the fact that the investigations were carried out on wood of Spanish origin, which has some different characteristics compared to the some species of Italian origin and not by failure validity of the visual grading.
Visual grading is always cautious and, therefore, can be used for the definition of the strength class, but it is not always responsive to real values.
In fact, the visual grading among the analysed elements did not identify those elements with the best features nor did it identify those with the worst features. We analysed seventeen elements, but only five elements were deemed suitable for structural use (5-1, 2-2, 7, 8, and 12). If we consider the five elements that have the best values of bending strength (elements 1-2, 10, 7, 5-1, 2-1), there are only two specimens that were identified by visual grading.
The mechanical properties of the element are often underestimated. This case has greater relevance in the case of reuse because, unlike the case of a new element, the load conditions that the wooden element is able to stand are already known. This can be taken as a reference to the maximum load in similar conditions of reuse.
The comparison between the strength classes identified with the visual grading and the real values resulting from experimental analysis reveals that a wooden element, according to current law and, although suitable, can be discarded and labeled for non-structural use. Whereas on one hand it is a guarantee of safety, on the other hand, the non-structural use of an element minimises its performances and yields a lower durability, with a consequential impact on sustainability, cushioning the embodied energy in a fewer number of years.
Analysing the obtained data from experimental tests carried out on 39 new elements of *Pinus Sylvestris* L. with section of 200 x 75 mm and category ME-2[19] (according to the classification made for marketing), it results that, in such cases, the resistant class defined through visual grading is widely cautionary. In all cases, the bending strength is superior to the characteristic value of the bending strength and only in the 0.87% of the cases is less then twice of the characteristic bending strength.
The category ME-2 for the *Pinus Sylvestris* L. corresponds to the class C18: in the 2.34% of cases, the modulus of elasticity is less then the modulus of average elasticity defined by the standard; in the 0.78% of the cases, the class C18 corresponds to the actual values are widely superior to those defined by the resistant class C18.
Therefore, there is a variance equal to 1.88% compared to 5.0% of the percentile value that is already a widely cautionary artefact.
Also, a comparison between the worst defects identified by the visual grading, i.e. these defects that actually affected the attribution of the resistance class and the defects that really affected the break with the aim to identifying if there is a correspondence between two analysis was carried out.
In tabular form the results of such analysis are presented [13].

1-1	UNI 11035: The worst defect that affects the definition of category (S3) is the knot 19.
	UNE 56544: The worst defects that affect the definition of the class (Rejected) are the group of knots 3-4-5 and wanes.
	BENDING TEST: The defects that affect the structural failure are the knots 3, 5, 18 and 25.
1-2	UNI 11035: The worst defects that affect the definition of the class (Rejected) are the wanes, the ring shakes and the knot 21.
	UNE 56544: The worst defects that affect the definition of the class (Rejected) are the wanes, the ring shakes and the group of knots 15-16.
	BENDING TEST: The defects that affect the structural failure are the wane between the faces C and D and the knot 29.
2-1	UNI 11035: The worst defects that affect the definition of the class (Rejected) are the wanes.
	UNE 56544: The worst defects that affect the definition of the class (Rejected) are the wanes and the knots 15-16-17.
	BENDING TEST: The defects that affect the structural failure are the knots 2 and 3 e the presence of a nail in the face B.
2-2	UNI 11035: The worst defect that affects the definition of the class (S2) is the knot 8.
	UNE 56544: The worst defect that affects the definition of the class (ME-2) is the group of knots 18-19.
	BENDING TEST: The defect that affects the structural failure is the knot 8.
3-1	UNI 11035: The worst defects that affect the definition of the class (Rejected) are the wanes.
	UNE 56544: The worst defects that affect the definition of the class (Rejected) are the wanes
	BENDING TEST: The defects that affect the structural failure are the knots 2, 3 and 26, the wanes and the fissures.
3-2	UNI 11035: The worst defect that affects the definition of the class (S3) is the knot 14.
	UNE 56544: The worst defect that affects the definition of the class (Rejected) is the knot 14.
	BENDING TEST: The defects that affect the structural failure are the knots 8, 9 and 14.
4-1	UNI 11035: The worst defect that affects the definition of the class (Rejected) is the knot 12.
	UNE 56544: The worst defects that affect the definition of the class (Rejected) are the group of knots 2-3 and the knot 12.
	BENDING TEST: The defects that affect the structural failure are the knot 3 and the knot 12.
4-2	UNI 11035: The worst defect that affects the definition of the class (Rejected) is the knot 13.
	UNE 56544: The worst defect that affects the definition of the class (Rejected) is the knot 13.
	BENDING TEST: The defects that affect the structural failure are the knots 34 and 39.
5-1	UNI 11035: The worst defect that affects the definition of the class (S2) is the knot 4.
	UNE 56544: The worst defects that affect the definition of the class (ME-2) are the knots 1, 2 and 15.
	BENDING TEST: The defect that affects the structural failure is the knot 3.
5-2	UNI 11035: The worst defects that affect the definition of the class (Rejected) are the knot 26 and the group of knots 6-7-8-9-10-11-12-13-14.
	UNE 56544: The worst defects that affect the definition of the class (Rejected) are teh knot 26 and the group of knots 6-7-8-9-10-11-12-13-14.
	BENDING TEST: The defects that affect the structural failure are the knots 10, 11 and 12.
7	UNI 11035: The worst defects that affect the definition of the class (S3) are the deformations.
	UNE 56544: The worst defects that affect the definition of the class (ME-2) are the deformations, the rate of growth and the knots 1 and 3.
	BENDING TEST: The element breaks due to the traction.

8	UNI 11035: The element do not present defects that negatively affect the class (S1).
	UNE 56544: The element do not present defects that negatively affect the class (ME-1).
	BENDING TEST: The element breaks due to the traction and the slope of grain.
10	UNI 11035: The worst defect that affects the definition of the class (Rejected) is the fissure on the face C (lenght 45 cm).
	UNE 56544: The worst defect that affects the definition of the class (Rejected) is the fissure on the face C (lenght 45 cm).
	BENDING TEST: The defect that affects the structural failure is the fissure on the face C (lenght 45 cm).
11	UNI 11035: The worst defect that affects the definition of the class (S3) is the knot 12.
	UNE 56544: The worst defect that affects the definition of the class (Rejected) is the ring shake.
	BENDING TEST: The defects that affect the structural failure are the knots 4 and 5.
12	UNI 11035: The worst defect that affects the definition of the class (S3) is the knot 14.
	UNE 56544: The worst defects that affect the definition of the class (ME-2) are he deformations, the group of knoys 2-3 and the knot 14.
	BENDING TEST: The defects that affect the structural failure are the knot 3 and a damage present underneath it.
13	UNI 11035: The worst defects that affect the definition of the class (Rejected) are the wanes and the knot 10.
	UNE 56544: The worst defects that affect the definition of the class (Rejected) are the wanes and the group of knots 6-7.
	BENDING TEST: The defect that affects the structural failure is the group of knots 1-2.
14	UNI 11035: The worst defect that affects the definition of the class (Rejected) is the twisting.
	UNE 56544: The worst defect that affects the definition of the class (Rejected) is the twisting.
	BENDING TEST: The defects that affect the structural failure are the knots 5 and 8.

Structural failure is conditioned by the defects present in the tensile part of the third medium. Therefore, the visual grading in more than half of the elements does not identify the defects that lead effectively to the breaking of the element. A correspondence between the worst defects identified by the visual classification and the break exists only when they are located in the tensile part subjected to maximum load.

Element n. 4-2 breaks bordering the area of maximum load due to the absence of significant defects in the area of maximum load.

Only in element n. 10 is the structural failure outside of the area of maximum load due to a significant crack, although there is a knot with a diameter of 2.8 cm. Element n. 13 breaks just outside the area of maximum load in correspondence with knots, although in the area of maximum load there are two wanes. The reduction of the section due to the presence of wanes conditions the break less than the knots, although located just outside the middle third. In all other cases, the failure occurs due to the defects that are in the area of maximum load that is in the middle third of the element. With the exception of element n. 10, when in the tensile part of the area of maximum load there are knots that cause the failure. Elements n. 7 and n. 8 do not present defects in the area of maximum load; nevertheless, they have strength values smaller than other elements that broke due to defects.

The visual grading, therefore, identifies defects that influence the structural failure only when the worst defects of the element are located at the tense part of the middle third. Among the parameters defined in the visual grading, the positioning of defects is not taken into consideration. In the case of new elements with the purpose to define uniform criteria for marketing, this is a precautionary measure. This is because it is not possible to know in advance how the wooden element will be used in reference to the location of use and, consequently, the side for the application of the load. In addition, it is not possible to know if the element will be cut or will be used in its original length, nor is it known at the time of sale what type of load it will bear. Unlike in the case of reuse of elements that have already lived a lifecycle, the visual analysis, made without considering the above-mentioned variables, produces inconsistent results because, in most cases, the rupture of the elements is significantly influenced by the worst defects located in the middle third and due to load modes, as seen from the data generated by experimental analysis. There is an important distinction in terms of process between the use of a new wooden element and the reuse of a wooden element that has already lived a lifecycle. In the first case, the strength class is defined and guaranteed by the manufacturer and by recognized certifications and markings. In the case of reuse, the technician must define, in the first analysis, the suitability of the element for structural reuse by visual grading, provided that, before the reuse, he must do all the markings and certifications required by the legislation. We have to consider that, even if we want to reuse an element of structural wood that has not undergone any kind of deterioration under the same load conditions of the first life cycle, the reuse implies that, when the element was installed for the first time, the legislation was different and, in most cases, the law was less precautionary (especially when we reuse elements with a life exceeding 50 years). The same elements, considered suitable in their first use, currently could be considered inadequate even under the same load conditions. The only chance for the designer/technician who wishes to proceed to reuse is to perform again the visual classification according to the parameters set by current regulations.

The elements that would be discarded today were used in the past; we are witnessing an increase in the level of performance required by the elements.

In the procedure of reuse, the knowledge of the history of the element is a decisive part. We have more information than the new elements, i.e. the loads that the element endured with a specific structural scheme, the occurred deformations, the placement of shrinkage cracks and the resistance to biological attack in a specific environmental class. (EN460:1994 Durability of wood and wood-based products. Natural durability of solid wood. Guide to the durability requirements for wood to be used in hazard classes).

If we treat a wooden element that has already undergone a life cycle with the same parameters used for a new element, it means that we are not considering these parameters in order to exploit its real potential.

It follows that, in the concept of reuse, the element cannot be considered without taking into account its new intended use. It is necessary to systematise the residual performance of an element, the information obtained by analysing the first life cycle and the possible intended uses. Considering the type and the location of the defects, it is possible to identify the structural scheme that minimizes the impact on the strength class. Once the structural scheme has been defined, we can visually categorise the element, considering the defects in the tense part a priority, in order to obtain qualitative results of a more realistic failure mode.

Therefore, initially the visual grading has to be carried out at a global level in order to evaluate the type and the placement of defects. With respect to knots or wanes, we must evaluate the opportunity to make cuts that increase the mechanical properties. Then, once the mode of reuse is defined, the visual grading must be done taking into account defects that are in parts of the element that are subject to greater stress, with the aim to identify the potential break modes most suited to reality in order to optimise the placement and use of the element.

It is possible to make such an analysis by applying higher coefficients for the localised defects in the areas most stressed. For example, in case of reuse according to a structural scheme of a supported beam, limited to the analysis of the knots of investigated elements, the application of a higher coefficient equal to 1.9 to the dimension of the present knots in the most stressed part, namely in the tensile part of the middle third (according to the different modalities established by the legislations), it would allow the most reliable results to be obtained, from a qualitative point of view.

It should be emphasised that such a coefficient cannot be assumed as valid in a generic sense, as the number of the investigated elements is too limited to ensure the reliability of the data. It can be considered, however, a moment of reflection for the definition of a specific investigation which allows the universal definition of the valid parameters according to the species of the element and to the modalities of reuse.

If the wooden element would be used again according to the static scheme of a cantilever (rarer case), in the visual grading it will be appropriate to take into account the worst defects placed in correspondence of the first third close to the restraint of the fixed joint. Generally, it can be said that the visual classification finalised to the reuse of a wooden element must take into account the static scheme and the type of load that would be applied and to evaluate according to these variables the worst defects present in the area mostly stressed.

For example, for the element 5, analysed with the visual grading, it is impossible for structural use due to the group of knots 6-7-8-9-10-11-12 and of knot 26, as both are positioned on the middle of the element. By dividing the element into two parts, it was obtained the part 5-2 that, because of such defects, it is not suitable for a structural use and the part 5-1 that instead presents a category S2 according to the Italian standard and ME-2 for the Spanish standard.

Hypothesising a reuse of the element 5-1 according to a static scheme of a supported beam with a uniformly distributed load, considering a flexural solicitation, it is analysed considering the present defects in the middle third with the aim of evaluating the optimisation of the reuse modalities. It results, in fact, that the element 5-1 presents inside the middle third, only the knot 3 on the side C, therefore, the element will be positioned in a way to ensure that the fibres around he knot 3 are compressed and not tensed, namely with the application of the load on the side A or on the side D.

Limits of the research and further developments

The reliability of the research is guaranteed by selecting wooden samples from demolition companies and by having carried out tests on element that have undergone a life cycle, greater in terms of years compared to the used wood of the safety systems in L'Aquila. Although this, the limited number of the analysed elements does not allow the identification of any coefficients that increase the defects located in the area of maximum load, but it does allow the identification of a different qualitative process, already valid in itself, with the aim to optimise the reuse.

The research, therefore, has more development opportunities in the definition of visual grading based on quantitative parameters that can be controlled by a specific model of computation. This model is able to detect the suitability for structural use with greater precision guaranteeing safety, but, at the same time, overcoming the paradox of

excluding elements that have sufficient mechanical properties for structural use and optimising the durability in reuse with environmental benefits.
The research requires, however, a significant number of elements to be subjected to analysis both in reference to the species and in reference to the size of the section.
A further field of research is the definition by experimental analyses of mechanical properties that in this research were neglected (because they depend on the analysed properties), i.e. making compression and traction tests in order to both demonstrate the correlation between the properties of the reused element and to assess, in this case, the compliance of existing visual grading and to identify a process for the optimisation of reuse.

Conclusions

The experimental analysis carried out on elements coming from the selective demolition have, in conclusion, allowed the identification the following results:

- when the defects that condition the visual category are composed by knots, wanes, fissures, ring shakes or biological alterations and are focused on a part of the element, the elimination of this part generates an increase of the performances of the part free from defects or that presents of minor entity;
- even if the visual classification results are precautionary and, therefore, usable for the definition of the resistant class, in many cases the real values of the elements that do not result in suitable for structural use are better that the real values of the elements that result in suitable for structural use; therefore, the performance of the elements are abundantly underestimated;
- the visual classification does not identify as worst the defects that actually lead to the break of the element, between the parameters of classification must be introduced also the static scheme and the type of load that will be applied and to evaluate, according to these variables, the worst defects present in the area most stressed;
- the analysis of the story of the element provides useful information for its reuse, as it allows the identification of the load conditions that the wooden element has been able to withstand and the modalities of deformation of the same, as well as the resistance in a specific class of use.

The made comparison shows that while the visual grading referred to new elements can be considered satisfactory in function of the logistical process to which the elements are submitted and of the impossibility to know in advance the use modalities; otherwise, for the elements that have already undergone a life cycle, although we agree on the validity of the visual grading as defined by the legislation at the level of safety, it is believed that the definition of modalities of visual grading that allows a greater correspondence with the real mechanical performances and the definition of a procedural process of specific classification would allow advantages not only in terms of safety, but also of environmental sustainability. Therefore, it remains an open matter that will have to be uniformly investigated with the aim of optimizing the reuse of wooden elements.
In conclusion, the analysis carried out in these tests shows the limits of visual grading and the need to define a more structured methodology that, with a different operating procedure, introduces additional phases compared with the current visual grading, increasing the level of safety and, at the same time, maximising reuse. These phases are briefly described below:

1. to carry out the visual grading as established by law, identifying qualitatively the worst defects of a wooden element as a whole;
2. to assess the opportunity to cut one or more parts of the element or divide it into several parts, with respect to the length of the element and the type and placement of defects, in order to increase the resistance class that derives from visual grading;
3. to carry out visual grading of elements, taking into consideration the worse defects with regard to the part of the element subject to greater stress;
4. to define construction methods which optimise the reuse of wooden elements through a correct positioning of the element according to the identified loads and defects.

The process has a qualitative nature that goes beyond numerical data that would represent a higher conditioning of the species.

6.4 _ Methodological- operative procedure for reuse

In light of the made analyses, it is possible to identify a methodological- operative procedure of reuse of wooden elements, with the aim to appreciate the residual performances and to increase the possibility of reuse. Once the safety systems have been removed, it is possible, analysing the characteristics of the elements, to identify the modalities of reuse for which the same element answers with efficient performance. Defining this correspondence, the current limit of lowering of residual performances is exceeded to ensure wide margins of safety. If, on one hand, it is appropriate to emphasise safety in the reuse, on the other hand, an excessive dejection of the potentiality of wooden elements, it becomes an unsustainable operation from an environmental and economic point of view.
The dejection of the performances must be precautionary with the aim to ensure a safe reuse, but it must, at the same time, take into account the actual performances of the elements with the aim to make full use of the grey energy. Furthermore, in cases of reuse of wooden elements, we have access to information that allows a more precise assessment to the modalities of reuse and to circumstances that occurred during the cycle of life.
In fact, the responsiveness of the wooden element to a specific class of environmental risk and its durability, in function of the species and the biological attack, are potentially more dangerous in the territories that are known. Even if, in fact, the legislation introduces modalities of evaluation of the durability, they are widely precautionary.

The analysis of state of conservation of the wooden element at the end of its first life cycle provides, instead, real information. Therefore, from this base of data it is possible to make assessments more congruent for the second life cycle, deciding if reuse the element in the same risk class or if it is more convenient to reuse in a lower risk class with the aim to increase the number of years of reuse.

Further relevant information available in case of reuse is the position and the intensity of the shrinkage cracks. In cases of not drying elements, the lesions occur unpredictably. The knowledge of the fissures allows both to place the most relevant favourably with respect to the applied load and/or to reduce the possibility of infiltration of water and to proceed to cut the wood sawn with the aim to increase the resistance of the element, when we have available round elements or "uso fiume" and "trieste" beams.

In wooden elements that already have undergone a life cycle, instead, we very often encountered permanent deformations (bow, crook, twist, and cup), that allow in the reuse a positioning to avoid water stagnation. Also, in cases of reuse with structural function it is possible to position the element with respect to the load conditions less onerous for the type of deformation of the element.

When the element to be used have lived the first life cycle with a structural function and we are aware of load conditions that the element was able to withstand in a specific position and according to a determined load scheme. In fact, as demonstrated by the previously described analysis, it is not possible to establish a truthful correspondence of the performance of wooden elements and the structures are dimensioned with large degrees of safety. In case of reuse, especially when it comes to historical elements that were dimensioned only in function of construction knowledge, we, instead, have at disposition information about the actual load condition. It is possible, therefore, a structural reuse dimensioned to the structure elements, taking these values as maximum.

This information is fundamental for the detection of the potential of wooden elements and for the optimization of the reuse in the second life cycle. If it is true that the evaluation of the performance of a wooden element according to the current legislation is already greatly precautionary, in cases of reuse, in the light of the available information, it is even more evident.

Therefore, to treat a wooden element that has undergone a life cycle according to the used canons for new wood excessively lowers the potentialities.

It is proposed a methodological-operative procedure aimed to identify the reuse possibility of a wooden element evaluating its own characteristics and using the information obtained from the analysis of the first life cycle. After the disassembly of the wooden element, the first step is measure the length:

- if the length is lower to 50 cm, the presence of paints and adhesives is verified:
  - if paints and adhesives are present, the element is transported to controlled landfill,
  - if there are not present paints or adhesives, the element is intended to combustion;
- If the length is greater or equal to 50 cm, a sample is extracted and analysed by microscope to identify the species.

After, we proceed to the evaluation of deterioration level. If the element presents forms of deterioration, it must be analysed and the deterioration distinguished as physical (damage for combustion, lesions, nails or screws) or biological (vegetable or animal attack).

If the deterioration is physical:

- in cases of deterioration for combustion we proceed to cut the damaged part;
- in cases of presence of lesions the position, the direction and intensity must be evaluated:
  - if the intensity of the lesion is less than a quarter of the length of the section, we proceed in the evaluation process;
  - if the lesion is passing, it has a length of 2/3 of the overall length of the element and it divides the wooden element into two parts with a homogeneous section, we proceed to cut the element along the lesion and we reuse two parts separately;
  - if the lesion is passing, it has a lesser length of 2/3 of the overall length of the element and it divides the wooden element into two pars with a homogeneous section, we proceed to perform a transversal cut of the wooden element in correspondence to the terminal point of the lesion, we get three elements, one with equal section to that of starting element and two with different section, the three elements continue the evaluation process, separately:
  - if the lesion is passing and divides the wooden element into two parts with uneven section, we proceed to cut the damaged part and to reuse the undamaged part;
- in case of deterioration for the presence of nails or screws, we proceed to extract or cut the intruders.

If the deterioration is biological:

- in case of severe widespread attack, the element can not be used and must be transported to landfill or undergoes combustion;
- in case of severe localized attack we proceed to cut the damaged part and to reuse the healthy part;
- in case of slight widespread attack, we proceed to the application of a curative treatment (chosen in function of the species permeability) or we proceed to cut the diseased part of the element with a reduction of the section and to reuse of the healthy part;
- In case of slight localized attack we proceed to the application of a curative treatment (chosen in function of the permeability of the species) or we proceed to cut the disease part of the element with reduction of the length and reuse of the healthy part.

It remains the assumption that any element with a length less to 50 cm even if derives from intentional cuts for the presence of fissures or of deterioration, must be transported to a landfill or undergo combustion.

In case we have enough information, we must consider the risk class of the first life cycle and the relative correspondence of the wooden element, evaluating the type and the level of deterioration in function of the number of years of life and the species.

Subsequently, in function of the species, we identify the natural durability and permeability of the wooden element (EN 150-1:1994 "Durability of Wood and Wood-based Products – Natural Durability of Solid Wood: Guide to the principles of testing and classification of the natural durability of wood"):

- if the element is durable, it is possible the reuse in all the environmental risk classes from 1 to 5;
- if the element is not durable, but is permeable, it is possible:
  - the reuse in environmental risk class 1 and 2;
  - the reuse in environmental risk class 3, 4, and 5 after preventive treatment;
- if the element is not durable and it is not permeable it is possible:
  - the reuse in environmental risk class 1;
  - the reuse in risk class 2 an 3, after preventive treatment.

Once identified, the possible classes of environmental risk (EN 460:1994 "Durability of wood and wood-based products. Natural durability of solid wood. Guide to the durability requirements for wood to be used in hazard classes"), directed towards specific reuses, we can proceed to the measurement of the section:

- if the selection is suitable to a non structural use, we proceed to finding destination of use, taking into account the environmental risk classes, previously defined (and consequently the possible curative treatments) and the responsiveness of the element in its first life cycle, to an use in a specific class;
- If the selection is suitable to a structural use, we proceed to the visual grading according to the current legislation (EN 14081-1:2005 +A1:2001 "Timber structures. Strength graded structural timber with rectangular cross section. Part 1: General requirements." and relative national legislation);
  - if the minimum requirements are satisfied, we proceed to the next analysis for the structural reuse;
  - if the minimum requirements are not satisfied due to the rate of growth, of the slop of grain, of the deformation and of the reaction wood the element is intended to a non structural use;
  - if the minimum requirements are not satisfied due to the knots, the wanes, the fissures and the ring shakes, we evaluate the possibility of cutting the part with defects that does not allow a structural reuse;

    specifically for what concerns the knots:
    - if more knots or group of knots are present and they are not within the expected limits, positioned in a diffuse way along the element, the element is intended to a non structural reuse;
    - if one or more knots or group of knots are present that do not fall within the set limits and they are positioned in a localised way in the element, it is possible to cut the part that hosting such knots, that is intended to a non structural use, for the remaining part free from defects, we proceed to subsequent analysis for the structural reuse;

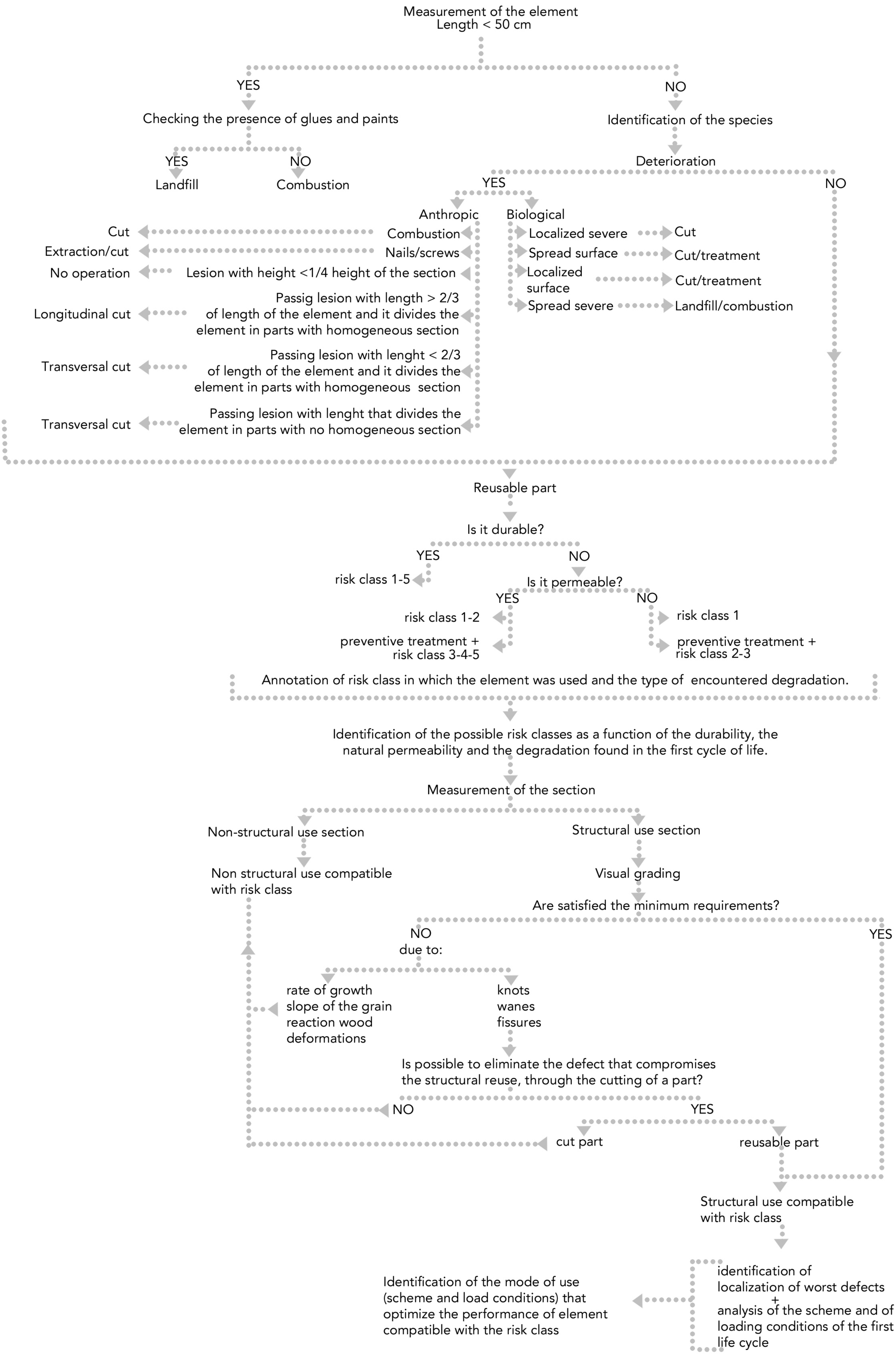
    for what concerns the wanes:
    - in cases in which it was carried out a cut in the longitudinal direction of the element in order to eliminate the wanes, if the projection of the wanes on a surface with respect to the width of the some surface is such as to reduce the section at the point of no longer being suitable to a structural use, the element is intended for a non-structural reuse without performing cutting operations;
    - in cases in which a cut in the longitudinal direction of the element was carried out in order to eliminate the wanes, if the projection of the wanes on a surface with respect to the width of the some surface is such as to not cause a significant reduction of the section of the element, we proceed to the next analysis for the structural reuse;

    for what concerns the fissures and ring shakes:
    - if the nature, the length and the positioning of the fissures is such as not to allow the removal through cutting, the element is not intended for structural reuse without making cutting operations;
    - if the nature, the length and the positioning of the cracks is such as not to allow the removal through cutting, we proceed to the next analysis for structural reuse;

In cases in which the visual grading has not identified defects that prevent a structural use, it must identify the localization of the worst defects and hypothesise a modality of reuse to limit the influence of these defects on the break. In cases in which the visual grading has identified defects that prevented a structural reuse such that they can be eliminated through cutting operations (knots, wanes, ring shakes, fissures), hereinafter to the performance of the latter, we will proceed to a new visual classification aimed to eliminate the worst defects and with respect to them, to identify the structural scheme and the load conditions that optimise the reuse.

The information inherent to the load conditions that the element in its first life cycle was able to withstand will be also be analysed when available.

The making system of such information will allow identifying the modality of structural reuse. In particular, once identified, the actual possibility of a structural reuse according to the characteristics of the element and, thanks to the reconditioning operations, we identify the functional destinations compatible with the risk classes previously identified for the specific element preparing, when required, the application of preventive treatments. In function of the present deterioration, of the own characteristics of the element and of the real possibilities of reuse, an element can undergo a variable number of reconditioning interventions and preventive treatments. Even if, in fact, each element presents in the optimal conditions of reuse, the possibility of potential reuse coming from the methodological-operative described procedure must be related with the real possibilities at a given time/place.


Measurement of the element
Length < 50 cm
YES
Checking the presence of glues and paints
YES
Landfill
NO
Combustion
NO
Identification of the species
Deterioration
YES
Anthropic
Combustion
Cut
Nails/screws
Extraction/cut
Lesion with height <1/4 height of the section
No operation
Passig lesion with length > 2/3 of length of the element and it divides the element in parts with homogeneous section
Longitudinal cut
Passing lesion with lenght < 2/3 of length of the element and it divides the element in parts with homogeneous section
Transversal cut
Passing lesion with lenght that divides the element in parts with no homogeneous section
Transversal cut
Biological
Localized severe
Cut
Spread surface
Cut/treatment
Localized surface
Cut/treatment
Spread severe
Landfill/combustion
NO
Reusable part
Is it durable?
YES
risk class 1-5
NO
Is it permeable?
YES
risk class 1-2
preventive treatment + risk class 3-4-5
NO
risk class 1
preventive treatment + risk class 2-3
Annotation of risk class in which the element was used and the type of encountered degradation.
Identification of the possible risk classes as a function of the durability, the natural permeability and the degradation found in the first cycle of life.
Measurement of the section
Non-structural use section
Non structural use compatible with risk class
Structural use section
Visual grading
Are satisfied the minimum requirements?
NO
due to:
rate of growth
slope of the grain
reaction wood
deformations
knots
wanes
fissures
Is possible to eliminate the defect that compromises the structural reuse, through the cutting of a part?
NO
YES
cut part
reusable part
YES
Structural use compatible with risk class
identification of localization of worst defects
+
analysis of the scheme and of loading conditions of the first life cycle
Identification of the mode of use (scheme and load conditions) that optimize the performance of element compatible with the risk class

6.5 _Levels of reuse

In function of the characteristics of the elements (species, dimension, defects and deterioration) and of relative treatments, it is possible to identify some reuse levels.
A distinction must be made between the elements that, in their first life cycle, had a structural function and for which, therefore, a non-structural reuse represents a lowering of the performance. Within the some level of reuse, it is possible to identify some variations conditioned by the deterioration, by natural durability and by impregnability.
For what concerns the applications of preventive treatments, in risk class 1, 2 or 3, they can be refused both in plant that on site in function of the level of impregnability of the wood: if the wood is impregnating in site or if it is impregnating in plant.
Otherwise, in risk class 4 and 5, the treatments must be made in plants in order to ensure a greater penetration of the preservative product.
If it is not possible, it is necessary to choose the reuse of the element in a lesser risk class.
The hierarchy of the reuse levels take into account both the characteristics and the residual performances of the wooden element that the number of reconditioning and preventive operations that must be carried out.
The technical/designer, after identifying the potential of a wooden element and consequently the reuse level, he may choose the modalities of reuse, maximising or partially exploiting the residual performance, identifying the compatibility with the lesser level of reuse (in function of the deterioration, of the durability and of the characteristics) lowering the performance that it needs to ensure. Otherwise, it is not possible to reuse the wooden element in a greater level than that set. In cases of doubt, the technical/designer will have to assign a level of use pejorative, with the aim to operate safety.

LEVELS OF REUSE FOR NON STRUCTURAL ELEMENTS

0	Controlled landfill
1	Combustion
2	Reuse in risk class 1/2 with reduced durability
3	Reuse in risk class 1/2 + cut/curative treatment + preservative treatment against insects
4	Reuse in risk class 1/2 + preservative treatment
5	Reuse in risk class 1/2 + curative treatment
6	Reuse in risk class 1/2
7	Reuse in risk class 3 + cut/curative treatment + preservative treatment against insects + preservative treatment against fungi
8	Reuse in risk class 3 + cut /curative treatment+ preservative treatment against fungi or alternately against insects
9	Reuse in risk class 3 + preservative treatment against fungi or alternately against insects
10	Reuse in risk class 3 + cut/curative treatment
11	Reuse in risk class 3
12	Reuse in risk class 4/5 + cut/curative treatment + preservative treatment against insects + preservative treatment against fungi
13	Reuse in risk class 4/5 + cut /curative treatment+ preservative treatment against fungi or alternately against insects
14	Reuse in risk class 4/5 + preservative treatment against fungi or alternately against insects
15	Reuse in risk class 4/5 + cut/curative treatment
16	Reuse in risk class 4/5

Levels of reuse			Characteristics of the element
0		Controlled landfill	Elements that have a high degree of deterioration or of reduced dimension, that are treated with adhesives or paints toxic in the combustion.
1		Combustion	Elements that have a high degree of deterioration or of reduced dimension.
2		Reuse in risk class 1/2 with reduced durability	Elements of species do not impregnable and do not resistant to attack of the species of insects present in the wood.
3		Reuse in risk class 1/2 + cut/curative treatment + preservative treatment against insects present in the palce	Elements of species that are impregnable and do not resistant to attack of the species of insects present in the place, in which there is a biological attack.
4		Reuse in risk class 1/2 + preservative treatment against the insects present in place	Elements of species that are impregnable and do not resistant to attack of the species of insects present in place.
5		Reuse in risk class 1/2 + curative treatment due to deterioration	Elements resistant to the attack of species of insects present in place where there is a biological attack.
6		Reuse in risk class 1/2	Elements of species resistant to insects attack and durable to fungi attack.
7	a	Reuse in risk class 3 + cut/curative treatment due to deterioration + preservative treatment in plant against fungi + preventive treatment in plant against the insects present in the place	Elements that present a biological attack, they have a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3 and are not resistant to the attack of the species of insects present in the place and are slightly impregnable.
	b	Reuse in risk class 3 + cut/curative treatment due to deterioration + preservative treatment in site against fungi + preventive treatment in site against the insects present in the place	Elements that present a biological attack, they have a natural class of durability to fungi equal to 3, 4 or 5 for the risk class 3 and are not resistant to the attack of the species of insects present in the place and are impregnable.
8	a	Reuse in risk class 3 + cut/curative treatment due to deterioration + preservative treatment in plant against fungi	Elements that present a biological attack, they have a natural class of durability to fungi equal to 3, 4, or 5 for the risk class 3 and are resistant to the attack of the species of insects present in the place and are slightly impregnable
	b	Reuse in risk class 3 + cut/curative treatment due to deterioration + preservative treatment in site against fungi	Elements that present a biological attack, they have a natural class of durability to fungi equal to 3, 4 or 5 for the risk class 3 and are resistant to the attack of the species of insects present in the place and are impregnable.
	c	Reuse in risk class 3 + cut/curative treatment due to deterioration + preservative treatment in plant against insects present in the place	Elements that present a biological attack, they have a natural class of durability to fungi equal to 1 or 2 for the risk class 3 and are not resistant to the attack of the species of insects present in the place and are slightly impregnable.
	d	Reuse in risk class 3 + cut/curative treatment due to deterioration + preservative treatment in site against insects present in the place	Elements that present a biological attack, they have a natural class of durability to fungi equal to 1 or 2 for the risk class 3 and are not resistant to the attack of the species of insects present in the place and are impregnable.

9	a	Reuse in risk class 3 + preservative treatment in plant against fungi	Elements that have a natural class of durability to fungi equal to 3, 4 or 5 for the risk class 3, are resistant to the attack of the species of insects present in place and are slightly impregnable.
	b	Reuse in risk class 3 + preservative treatment in site against fungi	Elements that have a natural class of durability to fungi equal to 3, 4 or 5 for the risk class 3, are resistant to the attack of the species of insects present in place and are impregnable.
	c	Reuse in risk class 3 + preservative treatment in plant against insects present in the place	Elements that have a natural class of durability to fungi equal to 1, 2 for the risk class 3, are not resistant to the attack of the species of insects present in place and are slightly impregnable.
	d	Reuse in risk class 3 + preservative treatment in site against insects present in the place	Elements that have a natural class of durability to fungi equal to 1, 2 for the risk class 3 and are not resistant to the attack of the species of insects present in place and are impregnable.
10		Reuse in risk class 3 + cut/curative treatment due to deterioration	Elements that present a biological attack, have a class of natural durability to fungi equal to 1 or 2 for the risk class 3, are resistant to the attack of the species of insects present in place.
11		Reuse in risk class 3	Elements that have a class of natural durability to fungi equal to 1 or 2 for the risk class 3, are resistant to the attack of the species of insects present in place.
12		Reuse in risk class 4/5 + cut/curative treatment due to deterioration + preservative treatment in plant against fungi + preventive treatment in plant against the insects present in the place	Elements that present a biological attack, have a class of natural durability to fungi equal to 3, 4 or 5 for the risk class 4/5, are not resistant to the attack of the species of insects present in place and are impregnable.
13	a	Reuse in risk class 4/5 + cut/curative treatment due to deterioration + preservative treatment in plant against fungi	Elements that present a biological attack, have a class of natural durability to fungi equal to 3, 4 or 5 for the risk class 4/5, are resistant to the attack of the species of insects present in place and are slightly impregnable.
	b	Reuse in risk class 4/5 + cut/curative treatment due to deterioration + preventive treatment in plant against the insects present in the place	Elements that present a biological attack, have a class of natural durability to fungi equal to 1or 2 for the risk class 4/5, are not resistant to the attack of the species of insects present in place and are impregnable.
14	a	Reuse in risk class 4/5 + preservative treatment in plant against fungi	Elements that have a class of natural durability to fungi equal to 3, 4 or 5 for the risk class 4/5, are resistant to the attack of the species of insects present in place and are impregnable.
	b	Reuse in risk class 4/5 + preventive treatment in plant against the insects present in the place	Elements that have a class of natural durability to fungi equal to 1 or 2 for the risk class 4/5, are resistant to the attack of the species of insects present in place and are impregnable.
15		Reuse in risk class 4/5 + cut/curative treatment due to deterioration	Elements that present a biological attack, have a class of natural durability to fungi equal to 1or 2 for the risk class 4/5, are resistant to the attack of the species of insects present in place.
16		Reuse in risk class 4/5	Elements that have a class of natural durability to fungi equal to 1or 2 for the risk class 4/5, are resistant to the attack of the species of insects present in place.

LEVELS OF REUSE FOR STRUCTURAL ELEMENTS

0	Controlled landfill
1	Combustion
2	Not structural reuse in risk class 1/2 with reduced durability
3	Not structural reuse in risk class 1/2 + cut/curative treatment + preservative treatment against insects
4	Not structural reuse in risk class 1/2 + preservative treatment
5	Not structural reuse in risk class 1/2 + cut/curative treatment
6	Not structural reuse in risk class 1/2
7	Not structural reuse in risk class 3 + cut/curative treatment + preservative treatment against insects+ preventive treatment against fungi
8	Not structural reuse in risk class 3 + cut/curative treatment + preservative treatment against insects or alternately fungi
9	Not structural reuse in risk class 3 + preservative treatment against insects or alternately fungi
10	Not structural reuse in risk class 3 + cut/curative treatment
11	Not structural reuse in risk class 3
12	Not structural reuse in risk class 4/5 + cut/curative treatment + preservative treatment against insects+ preventive treatment against fungi
13	Not structural reuse in risk class 4/5 + cut/curative treatment + preservative treatment against insects or alternately fung
14	Not structural reuse in risk class 4/5 + preservative treatment against insects or alternately fung
15	Not structural reuse in risk class 4/5 + cut/curative treatment
16	Not structural reuse in risk class 4/5
17	Structural reuse in risk class 1/2 + cut of localized defects with reduced durability
18	Structural reuse in risk class 1/2 with reduced durability
19	Structural reuse in risk class 1/2 + cut of localized defects + cut/curative treatment + preservative treatment against insects
20	Structural reuse in risk class 1/2 + cut of localized defects or alternately cut/curative treatment + preservative treatment against insects
21	Structural reuse in risk class 1/2 preservative treatment against insects
22	Structural reuse in risk class 1/2 + cut of localized defects + cut/curative treatment
23	Structural reuse in risk class 1/2 + cut of localized defects or alternately cut/curative treatment

24 Structural reuse in risk class 1/2

25 Structural reuse in risk class 3 + cut of localized defects + cut/curative treatment + preservative treatment against insects+ preventive treatment against fungi

26 Structural reuse in risk class 3 + cut of localized defects or alternately cut/curative treatment + preservative treatment against insects+ preventive treatment against fungi

27 Structural reuse in risk class 3 + preservative treatment against insects+ preventive treatment against fungi

28 Structural reuse in risk class 3 + cut of localized defects + cut/curative treatment + preservative treatment against insects or alternately preventive treatment against fungi

29 Structural reuse in risk class 3 + cut of localized defects or alternately cut/curative treatment + preservative treatment against insects or alternately preventive treatment against fungi

30 Structural reuse in risk class 3 + preservative treatment against insects or alternately preventive treatment against fungi

31 Structural reuse in risk class 3 + cut of localized defects + cut/curative treatment

32 Structural reuse in risk class 3 + cut of localized defects or alternately cut/curative treatment

33 Structural reuse in risk class 3

34 Structural reuse in risk class 4/5 + cut of localized defects + cut/curative treatment + preservative treatment against insects+ preventive treatment against fungi

35 Structural reuse in risk class 4/5 + cut of localized defects or alternately cut/curative treatment + preservative treatment against insects+ preventive treatment against fungi

36 Structural reuse in risk class 4/5 + preservative treatment against insects+ preventive treatment against fungi

37 Structural reuse in risk class 4/5 + cut of localized defects + cut/curative treatment + preservative treatment against insects or alternately preventive treatment against fungi

38 Structural reuse in risk class 4/5 + cut of localized defects or alternately cut/curative treatment + preservative treatment against insects or alternately preventive treatment against fungi

39 Structural reuse in risk class 4/5 + preservative treatment against insects or alternately preventive treatment against fungi

40 Structural reuse in risk class 4/5 + cut of localized defects + cut/curative treatment

41 Structural reuse in risk class 4/5 + cut of localized defects or alternately cut/ curative treatment

42 Structural reuse in risk class 4/5

Levels of reuse			Characteristics of the element
0		Controlled landfill	Elements that have a high degree of deterioration or of reduced dimension, that are treated with adhesives o paints toxic in the combustion.
1		Combustion	Elements that have a high degree of deterioration or of reduced dimension.
2		Not structural reuse in risk class 1/2 with reduced durability	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects[20] belonging to not impregnable species and resistant to the attack of insects presnet in the place.
3		Not structural reuse in risk class 1/2 + cut/curative treatment due to deterioration + preservative treatment against the insects present in the place.	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects belonging to impregnable species but not resistant to the attack of the insects present in the place, in which there is the biological attack.
4		Not structural reuse in risk class 1/2 + preservative treatment against the insects present in the place.	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects belonging to impregnable species but not resistant to the attack of the insects present in the place.
5		Not structural reuse in risk class 1/2 + cut/curative treatment due to deterioration	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, belonging to species resistant to the attack of the insects present in the place, in which there is the biological attack.
6		Not structural reuse in risk class 1/2	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, belonging to species resistant to the attack of the insects and durable to the attack of fungi.
7	a	Not structural reuse in risk class 3 + cut/curative treatment due to deterioration + preservative treatment in plant against fungi + preservative treatment in plant against the insects present in the place.	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, that present a biological attack, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are not resistant to the attack of the insects present in the place and are slightly impregnable.
	b	Not structural reuse in risk class 3 + cut/curative treatment due to deterioration + preservative treatment in site against fungi + preservative treatment in site against the insects present in the place.	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, that present a biological attack, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are not resistant to the attack of the insects present in the place and are impregnable.

8	a	Not structural reuse in risk class 3 + cut/curative treatment due to deterioration + preservative treatment in plant against fungi	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, that present a biological attack, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are resistant to the attack of the insects present in the place and are slightly impregnable.
	b	Not structural reuse in risk class 3 + cut/curative treatment due to deterioration + preservative treatment in site against fungi	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, that present a biological attack, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are resistant to the attack of the insects present in the place and are impregnable.
	c	Not structural reuse in risk class 3 + cut/curative treatment due to deterioration + preservative treatment in plant against insects present in place	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, that present a biological attack, have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 3, are not resistant to the attack of the insects present in the place and are slightly impregnable.
	d	Not structural reuse in risk class 3 + cut/curative treatment due to deterioration + preservative treatment in site against insects present in place	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, that present a biological attack, have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 3, are not resistant to the attack of the insects present in the place and are impregnable.
9	a	Not structural reuse in risk class 3 + preservative treatment in plant against fungi	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are resistant to the attack of the insects present in the place and are slightly impregnable.
	b	Not structural reuse in risk class 3 + preservative treatment in site against fungi	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are resistant to the attack of the insects present in the place and are impregnable.
	c	Not structural reuse in risk class 3 + preservative treatment in plant against insects present in place	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 3, are not resistant to the attack of the insects present in the place and are slightly impregnable.
	d	Not structural reuse in risk class 3 + preservative treatment in site against insects present in place	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 3, are not resistant to the attack of the insects present in the place and are impregnable.

10		Not structural reuse in risk class 3 + cut/curative treatment due to deterioration	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, that present a biological attack, have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 3, are resistant to the attack of the insects present in the place.
11		Not structural reuse in risk class 3	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 3, are resistant to the attack of the insects present in the place.
12		Not structural reuse in risk class 4/5 + cut/curative treatment due to deterioration + preservative treatment in plant against fungi + preservative treatment in plant against the insects present in the place	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, that present a biological attack, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 4/5, are not resistant to the attack of the insects present in the place and are impregnable.
13	a	Not structural reuse in risk class 4/5 + cut/curative treatment due to deterioration + preservative treatment in plant against fungi	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, that present a biological attack, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 4/5, are resistant to the attack of the insects present in the place and are impregnable.
	b	Not structural reuse in risk class 4/5 + cut/curative treatment due to deterioration + preservative treatment in plant against the insects present in the place	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, that present a biological attack, have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 4/5, are not resistant to the attack of the insects present in the place and are slightly impregnable.
14	a	Not structural reuse in risk class 4/5 + preservative treatment in plant against fungi	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, that present a biological attack, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 4/5, are not resistant to the attack of the insects present in the place and are impregnable.
	b	Not structural reuse in risk class 4/5 preservative treatment in plant against the insects present in the place	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, that present a biological attack, have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 4/5, are not resistant to the attack of the insects present in the place and are impregnable.
15		Not structural reuse in risk class 4/5 + cut/curative treatment due to deterioration	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, that present a biological attack, have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 4/5, are resistant to the attack of the insects present in the place.

16		Not structural reuse in risk class 4/5	Elements discarted by visual grading due to rate of growth, slope of grain, deformations, reaction wood or due to other disseminated defects, have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 4/5, are resistant to the attack of the insects present in the place.
17		Structural reuse in risk class 1/2 + cut of localized defects with reduced durability	Elements discarted by visual grading due to localized defects (knots, wanes, fissures) belonging to not impregnable species and not resistant to the attack of insects present in the place.
18		Structural reuse in risk class 1/2 with reduced durability	Elements accepted by visual grading belonging to not impregnable species and not resistant to the attack of insects present in the place.
19		Structural reuse in risk class 1/2 + cut of localized defects + cut/curative treatment due to deterioration + preservative treatment against insects present in the place	Elements discarted by visual grading due to localized defects (knots, wanes, fissures) belonging to impregnable species but not resistant to the attack of insects present in the place, in which there is the biological attack.
20	a	Structural reuse in risk class 1/2 + cut of localized defects + preservative treatment against insects present in the place	Elements discarted by visual grading due to localized defects (knots, wanes, fissures) belonging to impregnable species but not resistant to the attack of insects present in the place.
	b	Structural reuse in risk class 1/2 + cut/curative treatment due to deterioration + preservative treatment against insects present in the place	Elements accepted by visual grading belonging to not impregnable species and not resistant to the attack of insects present in the place, in which there is the biological attack.
21		Structural reuse in risk class 1/2 + preservative treatment against insects present in the place	Elements accepted by visual grading belonging to not impregnable species and not resistant to the attack of insects present in the place.
22		Structural reuse in risk class 1/2 + cut of localized defects + cut/curative treatment due to deterioration	Elements discarted by visual grading due to localized defects (knots, wanes, fissures) belonging to species resistant to the attack of insects present in the place, in which there is the biological attack.
23	a	Structural reuse in risk class 1/2 + cut of localized defects	Elements discarted by visual grading due to localized defects (knots, wanes, fissures) belonging to species resistant to the attack of insects and durable to the attack of fungi.
	b	Structural reuse in risk class 1/2 cut/curative treatment due to deterioration	Elements accepted by visual grading belonging to species resistant to the attack of insects present in the place and durable to the attack of fungi, in which there is the biological attack.
24		Structural reuse in risk class 1/2	Elements accepted by visual grading belonging to species resistant to the attack of insects and durable to the attack of fungi.
25	a	Structural reuse in risk class 3 + cut of localized defects + cut/curative treatment due to deterioration + preservative treatment in plant against fungi + preservative treatment in plant against insects present in the place	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that present a biological attack, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are not resistant to the attack of the insects present in the place and are slightly impregnable.
	b	Structural reuse in risk class 3 + cut of localized defects + cut/curative treatment due to deterioration + preservative treatment in site against fungi + preservative treatment in site against insects present in the place	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that present a biological attack, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are not resistant to the attack of the insects present in the place and are impregnable.

26	a	Structural reuse in risk class 3 + cut of localized defects + preservative treatment in plant against fungi + preservative treatment in plant against insects present in the place	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are not resistant to the attack of the insects present in the place and are slightly impregnable.
	b	Structural reuse in risk class 3 + cut of localized defects + preservative treatment in site against fungi + preservative treatment in site against insects present in the place	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are not resistant to the attack of the insects present in the place and are impregnable.
	c	Structural reuse in risk class 3 + cut/curative treatment due to deterioration + preservative treatment in plant against fungi + preservative treatment in plant against insects present in the place	Elements accepted by visual grading, that present a biological attack, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are not resistant to the attack of the insects present in the place and are slightly impregnable.
	d	RStructural reuse in risk class 3 + cut/curative treatment due to deterioration + preservative treatment in site against fungi + preservative treatment in site against insects present in the place	Elements accepted by visual grading, that present a biological attack, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are not resistant to the attack of the insects present in the place and are impregnable.
27	a	Structural reuse in risk class 3 + preservative treatment in plant against fungi + preservative treatment in plant against insects present in the place	Elements accepted by visual grading, that have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are not resistant to the attack of the insects present in the place and are slightly impregnable.
	b	Structural reuse in risk class 3 + preservative treatment in site against fungi + preservative treatment in site against insects present in the place	Elements accepted by visual grading, that have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are not resistant to the attack of the insects present in the place and are impregnable.
28	a	Structural reuse in risk class 3 + cut of localized defects + cut/curative treatment due to deterioration + preservative treatment in plant against fungi	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that present a biological attack, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are resistant to the attack of the insects present in the place and are slightly impregnable.
	b	Structural reuse in risk class 3 + cut of localized defects + cut/curative treatment due to deterioration + preservative treatment in site against fungi	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that present a biological attack, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are resistant to the attack of the insects present in the place and are impregnable.
	c	Structural reuse in risk class 3 + cut of localized defects + cut/curative treatment due to deterioration+ preservative treatment in plant against insects present in the place	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that present a biological attack, have a a natural class of durability to fungi, equal to 1, 2 for the risk class 3, are not resistant to the attack of the insects present in the place and are slightly impregnable.
	d	Structural reuse in risk class 3 + cut of localized defects + cut/curative treatment due to deterioration + preservative treatment in site against insects present in the place	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that present a biological attack, have a a natural class of durability to fungi, equal to 1, 2 for the risk class 3, are not resistant to the attack of the insects present in the place and are impregnable.

29	a	Structural reuse in risk class 3 + cut of localized defects + preservative treatment in plant against fungi	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are resistant to the attack of the insects present in the place and are slightly impregnable.
	b	Riuso strutturale in classe di rischio 3 + cut of localized defects + preservative treatment in site against fungi	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are resistant to the attack of the insects present in the place and are impregnable.
	c	Structural reuse in risk class 3 + cut of localized defects + preservative treatment in plant against insects present in the place	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 3, are not resistant to the attack of the insects present in the place and are slightly impregnable.
	d	Structural reuse in risk class 3 + cut of localized defects + preservative treatment in site against insects present in the place	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 3, are not resistant to the attack of the insects present in the place and are impregnable.
	e	Structural reuse in risk class 3 + cut/curative treatment due to deterioration + preservative treatment in plant against fungi	Elements accepted by visual grading, that present a biological attack, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are resistant to the attack of the insects present in the place and are slightly impregnable.
	f	Structural reuse in risk class 3 + cut/curative treatment due to deterioration + preservative treatment in site against fungi	Elements accepted by visual grading, that present a biological attack, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are resistant to the attack of the insects present in the place and are impregnable.
	g	Structural reuse in risk class 3 + cut/curative treatment due to deterioration + preservative treatment in plant against insects present in the place	Elements accepted by visual grading, that present a biological attack, have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 3, are not resistant to the attack of the insects present in the place and are slightly impregnable.
	h	Structural reuse in risk class 3 + cut/curative treatment due to deterioration + preservative treatment in site against insects present in the place	Elements accepted by visual grading, that present a biological attack, have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 3, are not resistant to the attack of the insects present in the place and are impregnable.
30	a	Structural reuse in risk class 3 + preservative treatment in plant against fungi	Elements accepted by visual grading, that have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are resistant to the attack of the insects present in the place and are slightly impregnable.
	b	Structural reuse in risk class 3 preservative treatment in site against fungi	Elements accepted by visual grading, that have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 3, are resistant to the attack of the insects present in the place and are impregnable.
	c	Structural reuse in risk class 3 preservative treatment in plant against insects present in the place	Elements accepted by visual grading, that have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 3, are not resistant to the attack of the insects present in the place and are slightly impregnable.
	d	Structural reuse in risk class 3 preservative treatment in site against insects present in the place	Elements accepted by visual grading, that have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 3, are not resistant to the attack of the insects present in the place and are impregnable.

31		Structural reuse in risk class 3 + cut of localized defects + cut/curative treatment due to deterioration	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that present a biological attack, have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 3, are resistant to the attack of the insects present in the place.
32	a	Structural reuse in risk class 3 + cut of localized defects	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 3, are resistant to the attack of the insects present in the place.
	b	Structural reuse in risk class 3 + cut/curative treatment due to deterioration	Elements accepted by visual grading, that present a biological attack, have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 3, are resistant to the attack of the insects present in the place.
33		Structural reuse in risk class 3	Elements accepted by visual grading, that have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 3, are resistant to the attack of the insects present in the place.
34		Structural reuse in risk class 4/5 + cut of localized defects + cut/curative treatment due to deterioration + preservative treatment in plant against fungi+ preservative treatment in plant against insects present in the place	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that present a biological attack, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 4/5, are not resistant to the attack of the insects present in the place and are impregnable.
35	a	Structural reuse in risk class 4/5 + cut of localized defects + preservative treatment in plant against fungi+ preservative treatment in plant against insects present in the place	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 4/5, are not resistant to the attack of the insects present in the place and are impregnable.
	b	Structural reuse in risk class 4/5 + cut/curative treatment due to deterioration + preservative treatment in plant against fungi + preservative treatment in plant against insects present in the place	Elements accepted by visual grading, that present a biological attack, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 4/5, are not resistant to the attack of the insects present in the place and are impregnable.
36		Structural reuse in risk class 4/5 + preservative treatment in plant against fungi+ preservative treatment in plant against insects present in the place	Elements accepted by visual grading, that have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 4/5, are not resistant to the attack of the insects present in the place and are impregnable.
37	a	Structural reuse in risk class 4/5 + cut of localized defects + cut/curative treatment due to deterioration + preservative treatment in plant against fungi	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that present a biological attack, have a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 4/5, are resistant to the attack of the insects present in the place and are impregnable.
	b	Structural reuse in risk class 4/5 + cut of localized defects + cut/curative treatment due to deterioration + preservative treatment in plant against insects present in the place	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 4/5, are not resistant to the attack of the insects present in the place and are impregnable.

38	a	Structural reuse in risk class 4/5 + cut of localized defects + preservative treatment in plant against fungi	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 4/5, are resistant to the attack of the insects present in the place and are impregnable.
	b	Structural reuse in risk class 4/5 + cut of localized defects + preservative treatment in plant against insects present in the place	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that have a a natural class of durability to fungi equal to 1 or 2 for the risk class 4/5, are not resistant to the attack of the insects present in the place and are impregnable.
	c	Structural reuse in risk class 4/5 + cut/curative treatment due to deterioration + preservative treatment in plant against fungi	Elements accepted by visual grading, that present a biological attack, have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 4/5, are resistant to the attack of the insects present in the place and are impregnable.
	d	RStructural reuse in risk class 4/5 + cut/curative treatment due to deterioration + preservative treatment in plant against insects present in the place	Elements accepted by visual grading, that presnet a biological attack, have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 4/5, are not resistant to the attack of the insects present in the place and are impregnable.
39	a	Structural reuse in risk class 4/5 + preservative treatment in plant against fungi	Elements accepted by visual grading, that have a a natural class of durability to fungi, equal to 3, 4 or 5 for the risk class 4/5, are resistant to the attack of the insects present in the place and are impregnable.
	b	Structural reuse in risk class 4/5 + preservative treatment in plant against insects present in the place	Elements accepted by visual grading, that have a a natural class of durability to fungi equal to 1 or 2 for the risk class 4/5, are not resistant to the attack of the insects present in the place and are impregnable.
40		Structural reuse in risk class 4/5 + cut of localized defects + cut/curative treatment due to deterioration	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that present a biological attack, have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 4/5, are resistant to the attack of the insects present in the place.
41	a	Structural reuse in risk class 4/5 + cut of localized defects	Elements discarted by visual grading due to localized defects (knots, wanes, fissures), that have a a natural class of durability to fungi equal to 1 or 2 for the risk class 4/5, are resistant to the attack of the insects present in the place.
	b	Structural reuse in risk class 4/5 + cut/curative treatment due to deterioration	Elements accepted by visual grading, that present a biological attack, have a a natural class of durability to fungi, equal to 1 or 2 for the risk class 4/5, are resistant to the attack of the insects present in the place.
42		Structural reuse in risk class 4/5	Elements accepted by visual grading, that have a a natural class of durability to fungi equal to 1 or 2 for the risk class 4/5, are resistant to the attack of the insects present in the place.

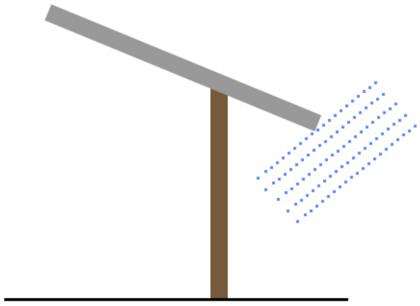
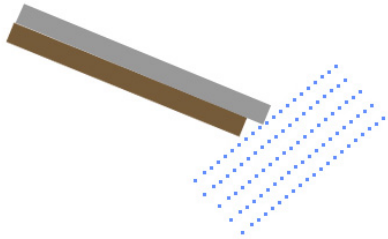
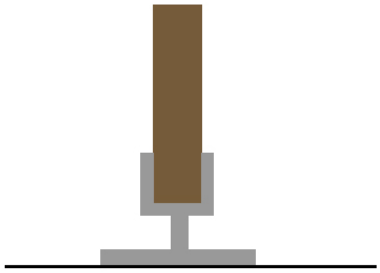
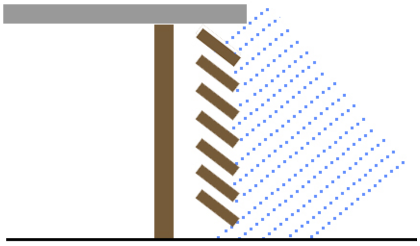
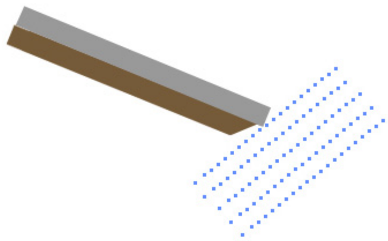
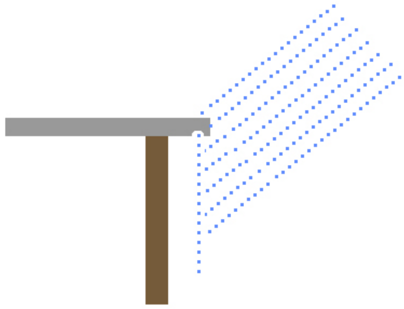
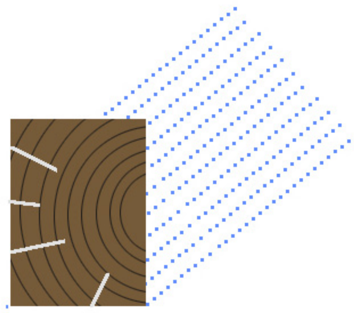
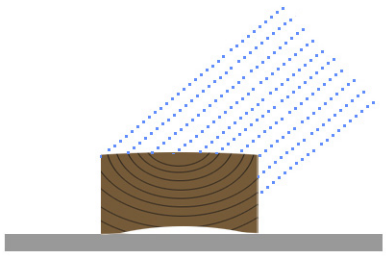
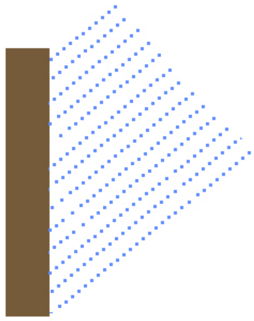
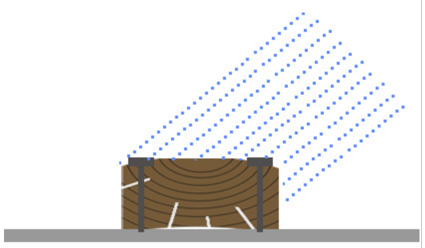
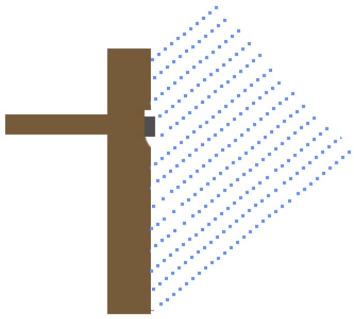
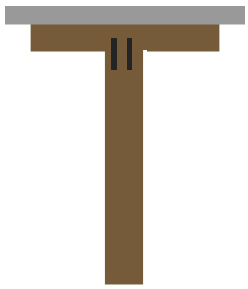
Hypothesising, for example, that a wooden element after analysis proves belonging to the reuse level for structural elements n.35, "Structural reuse in risk class 4/5 + cut/ curative treatment + preventive treatment against fungi + preventive treatment against insects," the technical/designer may choose in function of boundary conditions and of the needs if reusing it in the risk class 4/5 and to make the treatments listed above, evaluating mostly residual performances of the element or if reusing in one of the lower levels of reuse compatible with it. The compatibility between the levels is given, in this case, by the presence of biological deterioration, by the characteristic of impregnability of the wood, by the failure of resistance to insects present in place and by the natural durability equal to 3, 4, or 5 in risk class 4/5. The lower levels that correspond to all these parameters are the nn. 29h, 28d, 26d, 25b 20b, 19, 18, 13b, 12, 8d, 7b, 3, 2, 1 and 0.
In the reuse of each of these levels, the residual performances are underestimated because the element is used in classes of environmental lower risk, for non-structural uses, or it is intended for combustion or the landfill.
Other lower levels to 35 are not considered because they refer to wooden elements that have different characteristics or because they present only partially similar characteristics, being in a pejorative situation with respect to the element.
For example, the level n. 3 "Structural reuse in risk class 3" is not compatible because it refers to elements that have different residual performance, that are resistant to fungi attack in this risk class and that are resistant to insect attack, otherwise the level n. 34 "Structural reuse in risk class 4/5 with cut of localized defects + curative treatment or cut for deterioration + preventive treatment in plant against fungi attack + preventive treatment in plant against the attack of the species of the insects present in place" is not considered because, although it refers to impregnable wooden elements, are not resistant to insects and fungi attack, and with presence of biological attack (in the some way at level n.35).
It also refers to discarded elements through visual grading for the presence of localised defects and needs of an additional cutting operation compared to the level n.35, by representing a pejorative condition.
The reuse level attributed to it is less because the residual performance of the elements belonging to those levels is lower than residual performance of the elements belonging to level n.35.
In the same way, hypothesising that a wooden elements has residual performances attributable to reuse level n. 28 a "Structural reuse in risk class 3 + cut of localized defects + cut/curative treatment + preserving treatment against the insects or alternately preserving treatment against fungi," may be reused in such level exploiting most of its potentialities or may be reused in lower compatible levels. The wooden element attributed at such level presents localised defects conditioning its structural reuse and a biological attack, it is not resistant to fungi in risk class 3, but it is resistant to insects and it is little impregnable.
The lower compatible levels are nn. 22, 17, 8a, 5, 1, 0.

6.6 _Good practices for construction

After identifying the modalities of reuse, in the installation, it is necessary to use constructive measures which will increase the wooden durability and consequently to optimise the life cycle.
The use of elements that have already undergone a life cycle and; therefore, are seasoned, allows the knowledge of some characteristics that at the fresh state are not detectable.
In the first place, it is possible to evaluate the positioning and the width of shrinkage cracks, especially in the elements that include the pith and that, therefore, are certainly subject to fissures. In fact, happening during the sawing of the trunk at the fresh state, it is not possible to know before the positioning of the future fissures.
In addition to it, the use of the seasoned wood allows the knowledge of deformations (bow, crook, twist, and cup) both in their positioning that in their intensity, giving useful information for such positioning to avoid the accumulation of water in the concave part.
In particular, the wooden element must be protected from stagnation of water.
They are mainly adopted three strategies:

1. to protect wood through cantilever elements or supporting that for geometric and shape conformation favour the outflow of water;
2. to place/ to shape the wooden elements in such a way to favour the outflow of water;
3. to place the connections and the anchors for limiting the deformations and favour the outflow of water;

Some design strategies are universally valid for all materials that undergo deterioration when they are subjected to water, such as the protection of the elements by cantilevered, the inclined positioning or the protection of the connection points, other strategies are, instead, closely linked to woods because considered characteristics due to its nature and in particular to anisotropy. The protection of the cracked side reduces the possibility of water infiltration within of the element, in similar way the positioning of the side, with reflex angle, to bad weather remove to form the stagnation of water. In cases of elements that present a strong buckling, the horizontal positioning is recommended because on all sides to form, it runs the risk of accumulation of water, the chances are reduced in cases of positioning on the short side, but anyway they exist, therefore, operative modalities to avoid this phenomenon, is the vertical positioning.
The fixing the ends, generating a pressure reduces the possibility of water infiltration in the points of extremity and considerably limits further deformations. It occurs that the fixing at the ends proceed taking into account the positioning of existing shrinkage cracks, that must be free to run fluctuations in function of the variations of moisture, in case such deformations were prevented by a not correct fixing, this would cause a considerable increase in the depth of cracks.
It is possible to outline some design strategies of positioning[21] preventive to the deterioration:

WOOD PROTECTION THROUGH CANTILEVER OR SUPPORT ELEMENTS		
 Cantilevered roof to protect the wall from water.	 Cantilevered element to protect the head of wooden element from water.	 Separation from the soil to avoid the rise of water by capillarity.
POSITIONING/SHAPING OF WOODEN ELEMENT		
 Positioning of the element in an inclined way.	 Shaping of the element with the exposed side inclined.	 Shaping of the drip.
 Positioning with the cracked side protected.	 Positioning with the side with convex angle protected.	 Use of elements with strong twisting in vertical position.
POSITIONING OF CONNECTIONS/ANCHORAGES		
 Fixing at the ends and with the cracked convex side do not exposed to bad weather.	 Shaping the recess of the connection.	 Protection of points of connection.

NOTES

1. *G.Giordano, "Tecnica delle costruzioni in legno", Hoepli, Milano, 1999*
2. *In this discussion only the insects that attack the drying wood are analysed in detail, since the theme of research concerns the reuse of used wood and therefore that has just undergone the process of seasoning, even if the some wooden element had been undergone widespread attacks at the fresh state it would not be place in the building and therefore to date it does not constitute object of study.*
3. *For the preparation of the scheme the information present in Natterer Herzog Volz, "Atlante del legno", Utet, Torino 1996, page 57 have been partially used.*
4. *EN 335: 1995, Durability of wood and wood-based productos- Definition of hazard classes of biological attack.*
5. *UNI EN 460:1996 Durabilità del legno e dei prodotti a base di legno. Durabilità naturale del legno massiccio. Guida ai requisiti di durabilità per legno da utilizzare nelle classi di rischio*
6. *UNI EN 350-1:1996 Durabilità del legno e dei prodotti a base di legno. Durabilità naturale del legno massiccio. Guida ai principi di prova e classificazione della durabilità naturale del legno.*
7. *UNI CEN/TS 15003:2005 Durabilità del legno e dei prodotti a base di legno - Guida all'utilizzo di trattamenti termici per usi curativi contro gli organismi distruttori del legno.*
8. *It is defined "permeable" the wood that belongs to the impregnability class 1 both in the sapwood that in the heartwood, "resistant" the wood belonging to other classes.*
9. *Maria Diodato, Nicola Macchioni, Michele Brunetti, Benedetto Pizzo, Michela Nocetti, Paolo Burato, Lorena Sozzi, Elisa Pecoraro, Fernando Vegas López-Manzanares & Camilla Mileto "Understanding Spanish Timber Jack Arch Floors, Examples of Assessment and Conservation Issues", International Journal of Architectural Heritage: Conservation, Analysis, and Restoration, 2015, DOI: 10.1080/15583058.2015.1041193*
10. *The microscopic analysis were carried out in collaboration with Maria Diodato of the Universitat Politècnica de València in the "Servicio de Microscopía Electrónica" of the same University.*
11. *The results of the microscopic analysis of all elements are provided on digital media "Appendix A."*
12. *Paragraph 2.7 of the NTC 2088*
13. *The analysis about to the visual grading and the experimental tests are provided on digital media "Appendix B".*
14. *Forest Service US Dept. of Agriculture, "Woodhandbook", Forest Products Research, 1999*
15. *The relationship between G (shear modulus) and E (modulus of elasticity) is equal to about 1/16.*
16. *Belluzzi O., "Scienza delle costruzioni", Zanichelli, Bologna 2001, vol. 1*
17. *J. Bodig, B. Jayne, Mechanics of wood and wood composites, Krieger Publishing Company, United States, 1993*
18. *In the "Appendix C", on digital media a comparison between the characteristics values coming from the visual grading according to the Italian standard (UNI 11035) and Spanish standard (UNE 56544) and the mechanical characteristics resulting from the experimental analysis is performed.*
19. *The used data come from a study made by Javier Benlloch Marco.*
20. *For "other widespread defects", it means the presence of more knots or group of knots that exceed the expected limit by the visual grading for the structural reuse positioned in different areas on the element, the presence of wanes on both edges or of a dimension such that the longitudinal cut of the wanes will reduce the section of the wooden element to the point of being no more suitable for a structural reuse, the presence of cracks that have a length or a depth exceeding the expected limits by the visual grading for the structural use and for which a possible cut of the element would compromise the length or the section to the point of no longer being possible to have a structural use.*
21. *For the preparation of the scheme, the information present in Andrea Bernasconi, TU Graz, Promolegno, 2007 (http://www.iuav.it/SISTEMA-DE/Laboratori5/cosa-offri/formazione/seminari--/ultimo-eve/protezione-legno.pdf) have been partially used.*

7 _ STEEL ELEMENTS: OPTIMIZATION OF REUSE

7.1 _ Steel degradation

Corrosion is an electrochemical phenomenon that results in a chemical- physical interaction of the steel with its surrounding environment. It is an irreversible process that causes the gradual deterioration of its mechanical characteristics. There are different types of corrosion: generalised (uniform and non-uniform), localised (pitting, ulceration, crater and clique) and selective (dealloying, interdendritic, crystallographic and intergranular).

For the safety systems used in L'Aquila, the atmospheric corrosion due to the exposure of the structure to high humidity is widespread. The rate of corrosion is conditioned by many factors, including the relative humidity, the presence of condensate and air pollution. Another type of corrosion that results from incorrect executive choices, as well as the amount of oxygen in the environment, is galvanic corrosion. It triggers when two steel parts with a different amount of nobility are in contact. The less noble metal will corrode fast, because it acts as an anode from the steam of elections being generated.

The evaluation of the degradation of steel elements for their reuse is carried out in relation to the present level of corrosion and damage to the coating. Therefore, quantitative and typological analysis of degradation is reflected in the identification of the treatments to be applied, while the analysis of the causes that led to such impairment is reflected in the later stage of defining the procedures used for reuse as described below.

When corrosion is at a very early stage, it is possible to perform an approximate calculation of bearing capacity, which considers the reduction of the section and makes a comparison to the weight of the element before and after the elimination of the oxidized layer.

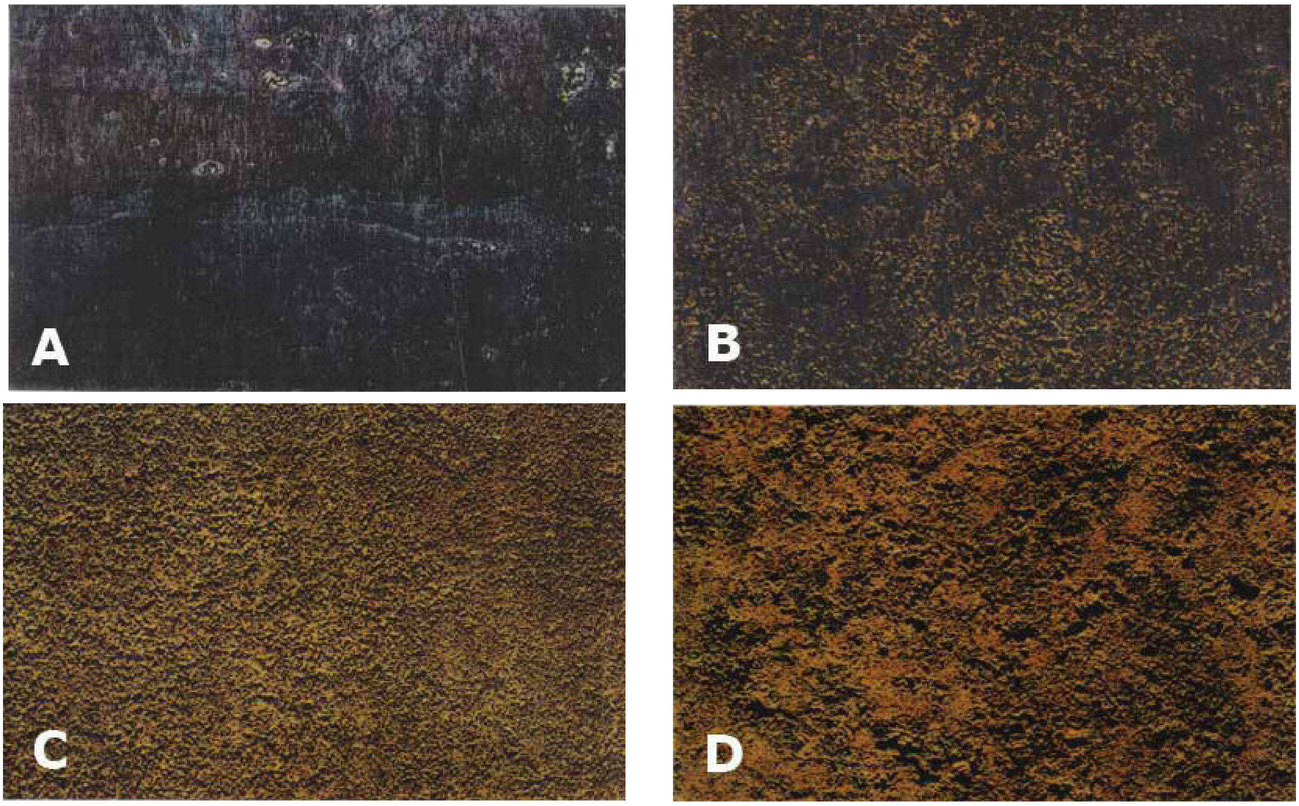
If corrosion is at an advanced stage, it is not possible to use this method due to the loss of the material's internal cohesion.[1]

The calculation was carried out with precautionary criteria, assessment of the level of corrosiveness that every element has upon its reuse remains at the technical evaluation or the real level in order to apply adequate preparations and preventive treatments.

The ISO 8501-1:2007 standard states the following: "Preparation of steel substrates before application of paints and related products – Visual assessment of surface cleanliness--Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings." This ordinance also defines four levels of corrosion of used steel that have never been treated with paint coating. The levels are influenced by the time of exposure to atmospheric agents:

- level A: steel surface largely covered with adhering mill scale but little, if any, rust. Generally this level is found following the process of hot-rolling;
- level B: steel surface which has begun to rust and from which the mill scale has begun to flake; generally this level is found following the process of hot rolling or the storage of the elements exposed to the weather for about 2 to 3 months;
- level C: steel surface on which the mill scale has rusted away or from which it can be scraped, but with slight pitting visible under normal vision. This level is found generally following the storage of the elements exposed to the weather for about 1 year;
- level D: steel surface on which the mill scale has rusted away and on which general pitting is visible under normal vision. Typically, this level is found following the storage of the elements exposed to the weather for about 3 years.

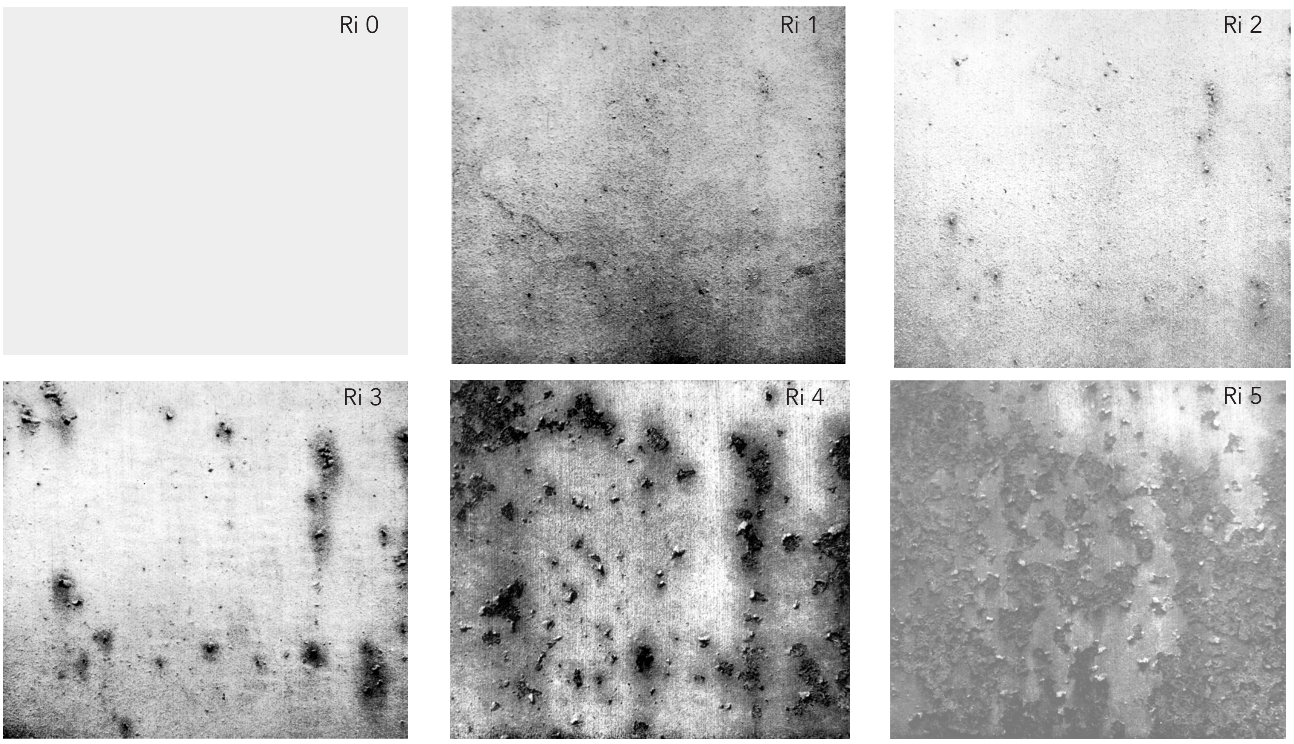
ISO 4628-3:2003 standard "Paints and varnishes--Evaluation of degradation of coatings--Designation of quantity and size of defects, and of intensity of uniform changes in appearance-Part 3: Assessment of degree of rusting." similarly defines the degree of rusting of painted surfaces



and provides comparative images[2]. The degree of rusting is the degree of formation of oxide that breaks down and passes through the painted surface expressed in percentage terms with respect to the total area:

- Ri 0: rusted area 0%
- Ri 1: rusted area 0,05%
- Ri 2: rusted area 0,5%
- Ri 3: rusted area 1%
- Ri 4: area ossidata 8%
- Ri 5: rusted area 40-50%

When we need a higher accuracy than the visual or manual inspection for painted surfaces, we can do an inspection with optical instruments (magnifiers and portable microscopes) and define the degree of rusting through comparative images provided by the standards.
The degree of rusting Ri 3 represents the maximum durability for the paint, out of which shall be carried out appropriate maintenance interventions.[3]
In reference to the painted steel elements, we have to consider further alterations of protective fabric (blistering, cracking, flaking and anthropogenic damage), with the aim



of establishing proper preparation and prevention treatments.

For the degree of blistering, standard ISO 4628-2:2003 states "Paints and varnishes--Evaluation of degradation of coatings--Designation of quantity and size of defects, and of intensity of uniform changes in appearance--Part 2: Assessment of degree of blistering."

For the level of cracking standard ISO 4628-4:2003, "Paints and varnishes--Evaluation of degradation of coatings--Designation of quantity and size of defects, and of intensity of uniform changes in appearance--Part 4: Assessment of degree of cracking.". The density, the dominant direction, the size (large: up to 1 mm thick, very large: over 1 mm thick) and the depth of cracking (depth equal to the thickness of the layer of painting) are all considered.

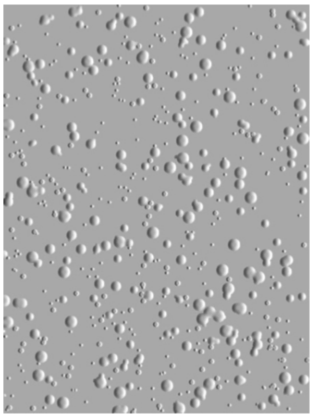
For the level of flaking, the standard ISO 4628-5:2003 "Paints and varnishes--Evaluation of degradation of coatings--Designation of quantity and size of defects, and of intensity of uniform changes in appearance--Part 5: Assessment of degree of flaking." is used. The area of flaking and size of sheets (grade 4: up to 30 mm, grade 5: over 30 mm) have to be considered.

The level of alteration gives an indication to the risk of rusting under the paint coating: a high alteration increases the risk. Therefore, the standard provides comparative images, which refer to situations of high intensity (level 4 and 5) and need extraordinary maintenance. Otherwise this research neglects the description of the situations with medium-low intensity (level 1, 2 and 3) that require regular maintenance in accordance with the arrangements programmed by the company that produced the coating system. In the case of extraordinary maintenance, it is necessary to make localized or total interventions and remove the damaged coating and then apply a new protective treatment. In the case of ordinary maintenance, cleaning treatment is sufficient. In the latter case, an assessment of the residual layer durability should be made on the protective layer over the existing alterations, which slightly, increase the risk of oxidation of the element, in order to plan future actions for reuse.

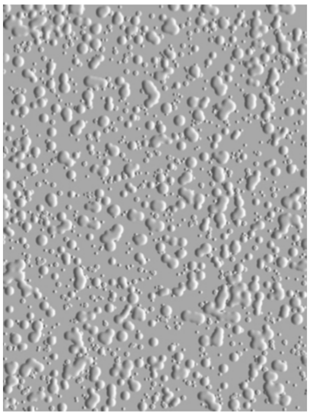
In the case of galvanized steel, the phenomenon of white rust can occur. White rust consists of zinc hydroxide, and to a lesser extent, carbonate and oxide, i.e. stains due to storage in humid environments. In this case, the element

BLISTERING LEVEL

Size 4

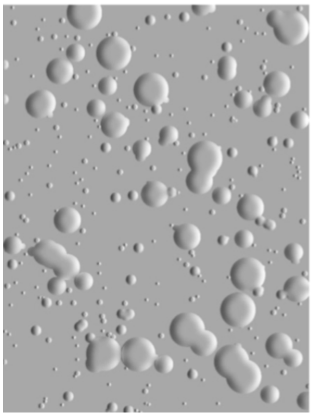


density 4

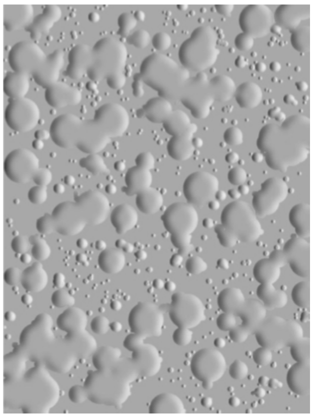


density 5

Size 5



density 4

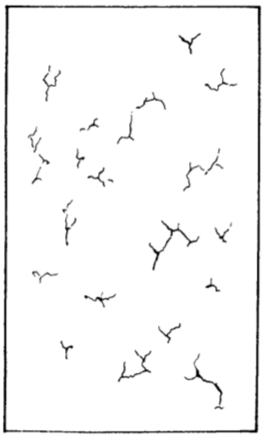


density 5

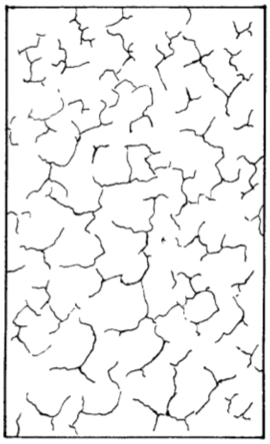
CRACKING LEVEL

Without prevailing direction

(area of specimen from 1dm^2 to 2 dm^2)



density 4

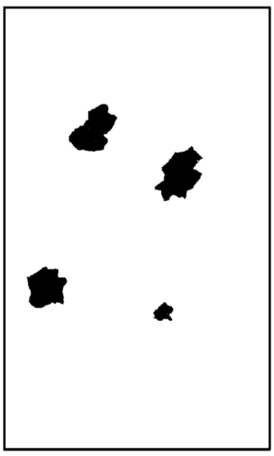


density 5

FLAKING LEVEL

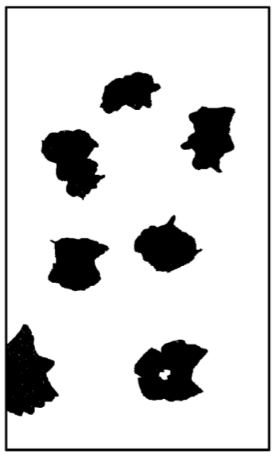
Without prevailing direction

(area of specimen form 1dm^2 to 2 dm^2)



density 4

flaknig area 3%



density 5

flaking area 15%

can be used after brushing (with rigid bristles), if the thickness of residue zinc is larger than the minimum thickness required by the standard (ISO 1461:2009 , "Hot dip galvanized coatings on fabricated iron and steel articles--Specifications and test methods"). Otherwise further treatments will have to proceed.
In order to increase the durability of the element, a maintenance cycle must be programmed.
An ideal maintenance cycle involves a remodelling intervention when there is a degraded area without corrosion equal to 3-5% of the total area, i.e., at time T, the restoration and overlay of the entire surface after a time equal to 1.5*T and the renovation of the entire treatment at time equal to 2.25*T. The operational reality the remodelling acts when the element has signs of damage and rust for a surface equal to 10% of the total area, i.e., at time T1, restoration and overlay of the entire surface after a time equal to 1.3 T1 and the renovation of the entire treatment at the time equal to 1.8*T1[4].
Although the overall durability of the element does not change, the postponement of the intervention increases costs because the retouching operations will be performed 2-3 times on a surface.
In the reuse, therefore, the level of corrosion and the hypothesis of reuse shall be determined with respect to corrosivity categories of the atmospheric environment and assessed on the basis of the opportunity to make a treatment of simple retouching, repair, or total reconstruction of the coating layer.
For example, suppose we want to reuse an element of steel that has a cycle of painting in zinc org/HB epoxy/polyester urethane, which has been installed in safety systems in L'Aquila in 2010. In 2015 (year of reuse), the element presents a damaged surface for a percentage of 1% and presents no signs of corrosion.
According to the ideal cycle of maintenance, the element, if used in an urban environment, has a residual durability of 10 additional years before arriving at a degradation equal to 3%. When it undergoes retouching operations, 17 years are added before needing a repair/overlay of entire surface and about 34 years before needing a renovation of the entire coating system. Therefore, assuming we want to reuse the element in the same city of L'Aquila, the element may be reused without undergoing any treatment for the realization of temporary architecture whose nominal life equals 10 years.
Otherwise, if it is considered appropriate to reuse the element for a permanent building, the technician can perform a touch-up intervention to eliminate the 1% of degradation and provide a maintenance plan that considers the element as new or, alternatively, does not make any treatment, but is considered in the maintenance plan the incidence of 5 years of life that the element has already fulfilled.

Cycle	**Surface preparation**	**Minimum thickness** (μm)	**Marine environment** (years)	**Urban environment** (years)
HB ST epossidico/HB ST epossidico/poliestere uretanico	SP 6	300	12 (16)	14 (21)
uretanico allo zinco/HB acrilico uretanico/acrilico uretanico	SP 10	250	12 (16)	14 (21)
zinco inorg./HB epossidico/HB epossidico	SP 10	280	12 (16)	15 (22,5)
zinco inorg./HB acrilico uretanico/HB acrilico uretanico	SP 10	280	12 (16)	15 (22,5)
zinco inorg./HB epossidico/poliestere uretanico	SP 10	225	12 (16)	15 (22,5)
zinco inorg./HB epossidico/ acrilico uretanico	SP 10	225	12 (16)	14 (21)
zinco epossidico/ HB epossidico/HB epossidico	SP 10	280	12 (16)	14 (21)
zinco org./HB acrilico uretanico/HB acrilico uretanico	SP 10	280	12 (16)	15 (22,5)
zinco epossidico/ HB epossidico/poliestere uretanico	SP 10	225	12 (16)	14 (21)
zinco inorg./HB vinilico/HB vinilico	SP 10	280	12 (16)	13 (19,5)
zinco inorg.	SP 10	75	(15)	(17)
zinco org.	SP 10	75	(6)	(5)

HB= high thickness; SP10= white metal sandblasting; ST= surface tollerant

Fig. 1 _ Expected life before the first remodelling for elements that have suffered certain types of paint in marine and urban environments. The values are based on an ideal maintenance cycle. Within parentheses, the values refer to a real maintenance cycle.

7.2 _ Steel treatments

Superficial preventive treatments contain the consecutive application of:

- preparation treatment: it aims to eliminate dirt or corrosion in progress;
- prevention treatment: it aims to prevent the occurrence of corrosion as a function of the nominal life request to the building.

The preparation treatments provide clean surfaces according to a different degree, depending on the used treatment and corrosivity of the atmospheric environment classes. The standard ISO 8501-1:2007, "Preparation of steel substrates before application of paints and related products – Visual assessment of surface cleanliness--Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings," defines the primary preparation when impurities are removed and the metal surface is laid bare by reaching the following degrees of preparation:

- with manual or mechanical cleaning:
  - St 2: the element is free from oiliness, poorly adhered materials, and by a light layer of rust;
  - St 3: the element is released from oiliness, poorly adhered materials and is partly free from rust;
- with blast cleaning:
  - Sa 1: with soft sandblasting or brushing, the element is free from oiliness and poorly adhered materials;
  - Sa 2: with a commercial sandblaster, the element is free from oiliness, calamine, surface contamination and it has a greyish colour;
  - Sa 2 ½: very accurate sand blasting to almost white metal, the element is free from oiliness, dirt and rust. It has a whitish tint with traces of impurities in small patches or strips;
  - Sa 3: much boost blasting or white metal blasting, the element is completely free of any oiliness, dirt and rust and it has a whitish uniform tint with flame cleaning;
- with flame cleaning:
  - FI: element is partially free from calamine and rust.

The standard ISO 8501-2: 1994, "Preparation of steel substrates before application of paints and related products -- Visual assessment of surface cleanliness -- Part 2: Preparation grades for previously painted steel substrates, after localised removal of previous coatings." defines the secondary preparation when impurities are removed and the metal surface retains its protective paint layer. It reaches the following levels of preparation:

- with localized manual or mechanical cleaning:
  - P St2: element is punctually released from oiliness and poorly adhered materials and by a light layer of rust;
  - P St3: element is punctually released from oiliness, poorly adhered materials and is partly free from rust;
- with localized cleaning from sandblasting:
  - P Sa 2: accurate or commercial sandblaster, the element is punctually free from oiliness, calamine, surface contamination and has a greyish colour;
  - P Sa 2 ½ very accurate sand blasting getting almost white metal, the element is punctually free from oiliness, dirt and rust, it has a whitish tint with traces of impurities in small patches or strips;
  - P Sa 3: much boost blasting or white metal blasting, the element is punctually free of any oiliness, dirt and rust and it has a whitish uniform tint;
- with localized cleaning with mechanical abrasion
  - P Ma: element is locally free of dirt, oiliness and rust.

In the evaluation of the degree of initial corrosion and consequently of the cleaning treatments, with regards to the non-coated surfaces and surfaces with metallic coatings (thermally sprayed, hot galvanized, electro-galvanized, and painted with industrial primer), once the covering layer (locally or totally) is removed, we have to refer to the classes of corrosion contained in the ISO 8501- 1 (A, B, C, D). For the painted surfaces, it is necessary to refer to the classification of the standards from ISO 4628- 1 to ISO 4628-6 (rusting, blistering, flaking, cracking, and chalking) if the coating is present. It is necessary to refer to ISO 8501-1 (A, B, C, D) if the coating is completely removed.
In accordance with ISO 12944-2:1998, "Paints and varnishes-Corrosion protection of steel structures by protective paint systems-Part 4: Types of surface and surface preparation," the preparation treatments aimed to clean a steel element are:

- water, solvents or chemicals:
  - cleaning with water: a stream of fresh water is directed on the element with variable pressure depending on the dirt/filth; in case of the presence of oil and fats, it is necessary to add detergents;
  - cleaning with vapour: a jet of vapour is directed over the element; in the presence of oil and grease, it is necessary to add water before steaming detergents;
  - cleaning with emulsifier/alkaline products: using emulsifying/alkaline products to remove grease and oil and then rinsing with fresh and clean water;
  - cleaning with organic solvents: napkins impregnated with solvents can be used when a small area that has grease or oil has to be treated;
  - cleaning with chemical conversion (for example phosphating, and chromating): it is used with hot-dip galvanised surfaces, sherardized surfaces and it is necessary to rinse with water;
  - chemical pickling: a paste with solvent is used when there are soluble paints solvents or alkaline paste for saponifable paints; it can be applied in limited parts to remove the existing paint;
  - acid pickling:it consists of dipping the element into an acid bath (like sulphuric or hydrochloric acid) to remove rust; the processing residues (usually heat treatment) cannot be carried out on the site, but only in the plant; it is typically used prior to galvanizing and results in a reduced level of roughness;
- cleaning with flame: it can be used on plates with a thickness greater than 5 mm; the element is treated with an oxyacetylene flame; impurities are removed by the action of flame, both thermal and mechanical, to remove rust and rolling debris; before the preventive treatment, the surface should be treated with wire

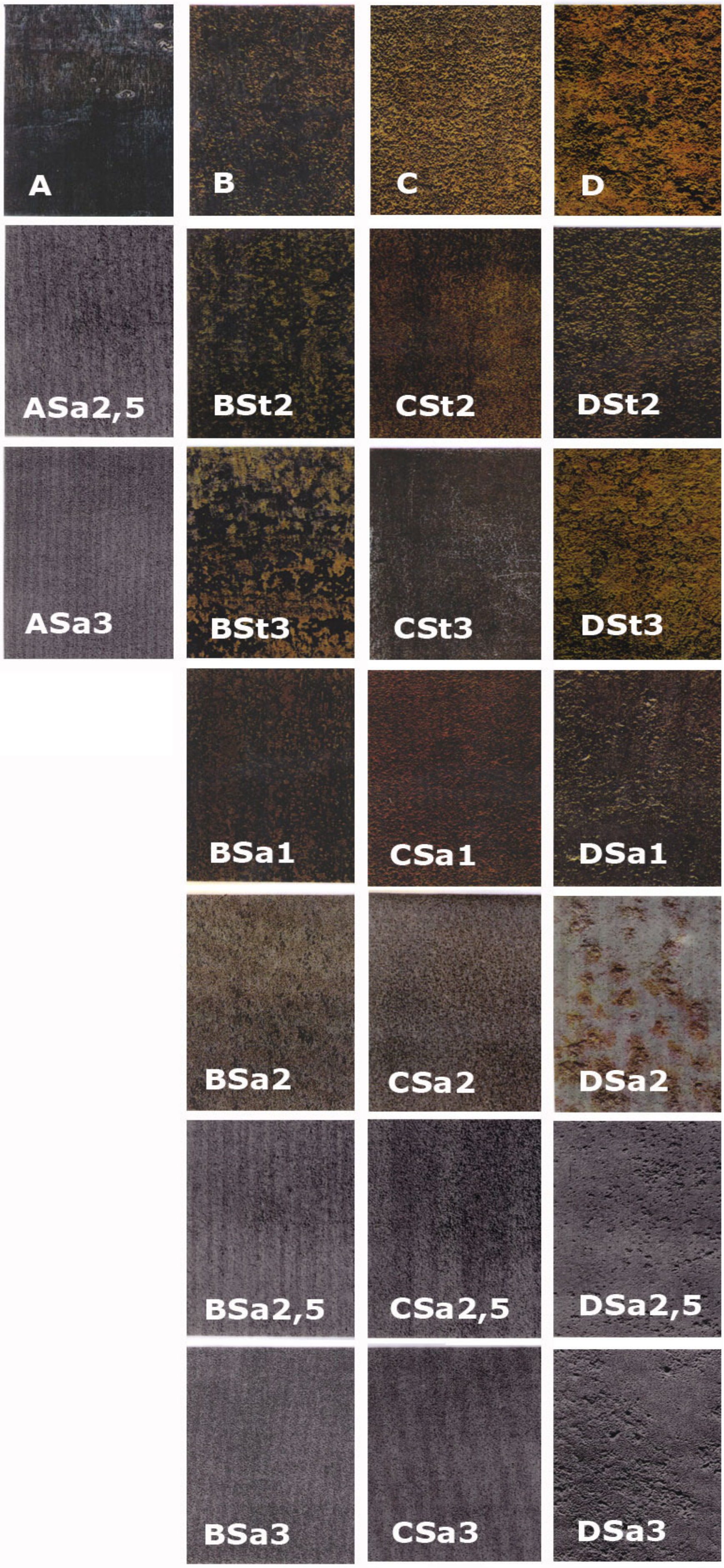


Fig. 2 _Preparation tretment and corrosivity categories

brushing, pickling or sandblasting and debris should be cleaned due to treatments;

- abrasive action:
  - with manual (non-motorised) instruments[5]: llike brushes, scrapers, and metallic abrasives; it proceeds by removing the rust, weld, paint residue or flaking; the residues are eliminated using aspiration or compressed air; it is possible to reach a state of preparation equal to St 2;
  - with motorized instruments[5]: rotating abrasive instruments, sandpaper, drills and needle guns proceed by removing the rust through rolling tools, welding residues or other debris, by using a rotating tool or impact and then removing the flaking paint with metal brushes or grinding; it is necessary to be careful to not completely eliminate the friction of the surface for the purposes of protective treatments; by using aspiration or compressed air, the residues are eliminated; it is possible to reach a state of preparation equal to St 3;
  - dry sandblasting: surface is invested with small, solid elements immersed in gaseous fluid, which is launched at high speed so as to be abrasive against the oil and grease, impurities, little adherent rolling residues and rust; dry blasting can take place through:
    - centrifugal method in stationary or mobile units: solid elements are moved from fans or centrifugal wheels; it is used when there are accessible surfaces with all grades of corrosion[6]; it is possible to reach a state of preparation equal to Sa 3;
    - method with compressed air: elements are incorporated into the air launched against the element and is applied to clean large elements with all grades of corrosion[6]; it is possible to reach a state of preparation equal to Sa 3;
    - method with recovery with suction: it is similar to the compressed air system, but the nozzle is located in intake system applied on the surface of the steel, to gather solid elements that were launched after the abrasion. The solid elements do not produce dust during processing. It is suitable for the cleaning of regular shaped elements, but it needs more time than other methods. It can be used for cleaning elements with levels of corrosion A, B and C[6] and it is possible to reach a state of preparation equal to Sa 2 ½ and by increasing the time of treatment and the state of preparation to Sa 3;
  - wet blasting: the surface is wet with small natural solid elements immersed in liquid and are launched at high speed so as to be abrasive against the oil and grease, impurities and poorly adhered rolling residues and rust. In the liquid, detergents can also be added, with the aim to remove fat and oil; wet blasting can take place through:
    - method with wet compressed air: it is similar to the compressed air method, but a small amount of liquid in the air blast is added (generally clean water with the addition of corrosion inhibitor). This reduces the machining dust (dust less than 50 pm do not remain suspended in the air). Water consumption is around 15-25 l/h; it is used with all levels of corrosion[13] and it is possible to reach a state of preparation equal to Sa 3;
    - method with compressed air and wet abrasive: it is similar to the previous method, but a small amount of liquid at the bottom of the injector is added, in order to obtain a stream with air, water and abrasive particles; it has the advantage that it can be used both a continuous and intermittent manner; this method can be applied to all kinds of elements, including large ones, when prompted for a low level of soluble salts on the surfaces; it is necessary to consider that the presence of water can cause a mild oxidation of the element and that before applying the protective treatment, it is important to wait until surfaces are dry; the method is used with all levels of corrosion and it is possible to reach a state of preparation equal to Sa3;
    - wet method with very fine abrasive: the abrasive with fine grain size is introduced into a liquid (usually water). It is suitable for elements that require a smooth surface. For small elements, it is used to reduce the amount of soluble salts present on surfaces;
    - method with pressurized liquid: into the liquid (usually water) and the pressurized stream is directed on the element (this will use less water than the method with wet compressed air) with levels of corrosion A, B and C[13]. The method allows to achieve a level of preparation equal to Sa 3; while the level of corrosion D is a level of preparation equal to Sa 2 ½.

The effectiveness of prevention treatments, the coatings in particular, is conditioned by the presence of oxide on the application substrate of calamine, contaminants (salts, dust, grease, etc.) and by the geometry of the element. Therefore, the standard ISO 8502:2006, "Preparation of steel substrates before application of paints and related products--Tests for the assessment of surface cleanliness," establishes tests to assess the level of cleanliness of the surface[7]. The tests that can be performed in site are listed below:

- measurement of soluble iron corrosion products for surfaces that have been cleaned by sandblasting with a state of preparation equal to Sa 2 ½ or above; it is not applicable to manually cleaned surfaces and can be completed with several methods:
  - controlled washing is carried out with water, which eliminates a part of the soluble salts present in the substrate to be tested; the water that was used in the washing is tested by a colorimetric detector (paper indicators 2.2' bipyridine with a margin of sensitivity between 5 and 250 mg/l);
  - controlled washing is carried out with water and a part of soluble salts present in the substrate to be verified is deleted; the conductivity of the water used in the washing is calculated; an increase in conductivity is

related to the presence of salts and it requires specific equipment;

- use of tests consisting of paper impregnated with potassium hexacyanoferrate; by using hand sprayer, water is sprayed on a small surface; the evaporation of water is expected to obtain a moist layer; paper is applied for 2-5 seconds; if there are soluble salts, the test paper looks blue speckled, corresponding to the contaminated parts of the surface;
- in an emulsion, detectors of salts (like potassium hexacyanoferrate or 2.2' bipyridine) are placed and by sprayed on the surface; depending on the bluish colour, it is possible to assess the presence of soluble salts;
- visual inspection via a magnifying glass with a minimal increase of 20 times, which verifies the presence of elements of corrosion as white crystals; it is not very reliable, because with high humidity, the crystals dissolve and they are not visible; also, it does not give information with respect to the nature of the salts present;

- determination of dust present on the surface: the method of pressure-sensitive adhesive string allows for the identification of the dust particles with respect to quantity and size; it can only be used on a steel element that before cleaning presented a level of corrosion equal to A, B, or C and not in the case of level equal to D; the first three laps of the adhesive roll have to be discarded; a piece of 200 mm in length is taken; the adhesive string is made to stick to the support by manual pressure; a finger is put on one extremity and it is moved 3 times in each direction while applying pressure at a constant speed so that each movement lasts between 5 and 6 seconds and then the test specimen is removed; through the test samples provided by legislation, it is possible to estimate the amount of dust and size; it is necessary to perform at least 3 trials.

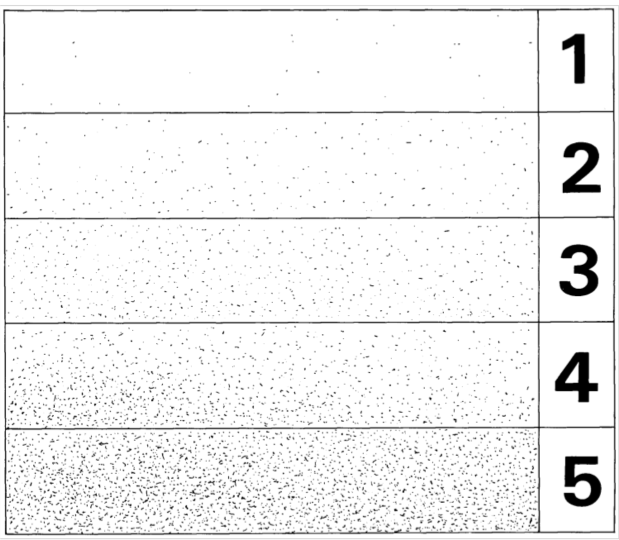
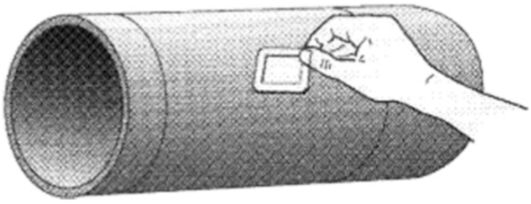


Fig. 3 _Comparative images with quantities of dust

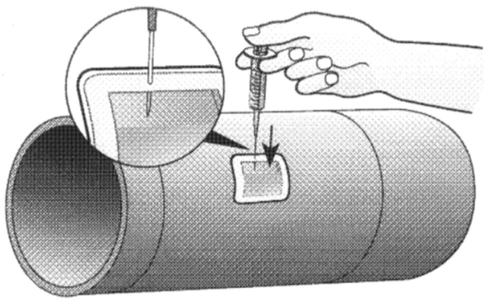
Class 0: no visible dust with a magnification of less than 10 times.
Class 1: dust visible with a magnification less than 10 times (less than 50 mm in diameter).
Class 2: dust visible with a normal or correct view (diameter between 50 mm and 100 mm).
Class 3: dust visible with a normal view or correct display (up to 0.5 mm diameter).
Class 4: dust with a diameter between 0.5 mm and 2.5 mm.
Class 5: dust with a diameter greater than 2 mm.

- test for turbidimetric determination of surface density of soluble sulfates in water implements the Bresle method; soluble sulphates in water are extracted from the substrate and a precipitating reactor Ba $(NO_3)_2$ or $BaCl_2$ and a flocculant are added; the spectral absorption coefficient dispersion depends on the sulphate content and can be used to determine the mass concentration of retrieved sulfate; it is possible to calculate the density through a formula;
- quantitative measurement of chloride present on the surface via an ion detection tube, a controlled cleaning is made; part of the chlorides are soluble in water and an analysis is carried out using a detection tube containing silver chrome that changes colour; in detail pipe ends are cut and one of the extremes is plugged in the testing solution; the tube is held in a vertical position; when the solution reaches the upper end, the value is read on the scale; the solution of the concentration of chlorides (mg/l), clear thanks to a slight colour variation due to the reaction with chloride, has to reach the top of the tube in 5 minutes, otherwise the test has to be repeated. 5 tests shall be carried out at a temperature between 5° and 80°;
- extraction of soluble contaminants in water with the Bresle method and the method for conductometric determination of soluble salts in water evaluates the total surface density of soluble salts in water (chlorides and sulphates); an adhesive plaster with a recess in the middle is used; the solvent (like distilled water) is injected into the cavity with a syringe and then retrieved in the same way; the operation is repeated 3 times; the solvent that also contains contaminants is placed into a container to be analysed; the electrodes of the conductivity meter are flooded with contaminated water and it is possible to calculate the total surface conductivity and density;
- method for determination of volume of iron ions soluble in water, a sample is extracted with the Bresle method or some other similar method; then the solution is made acidic by phosphoric acid (ML) and a chrome solution is inserted using diphenylamine sulfonate as an indicator (1 quantity = (0.05 ± 0.002) ml); the solution with chrome is added for a unitary amount to record a change in the solution from colourless to blue-grey and finally to purple, depending on the amount added to the colour change in purple; it is possible to assess the surface density of the iron ions by using comparison tables that are described

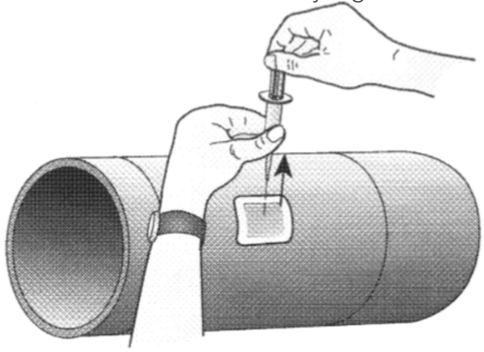
Placement of adhesive plaster



Insertion of the solvent with syringe



Removal of the solvent with syringe



Inserting into container for analysis.

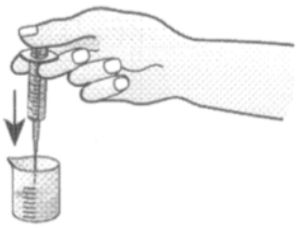


Fig. 4 _Process for the evaluation of soluble contaminants in water

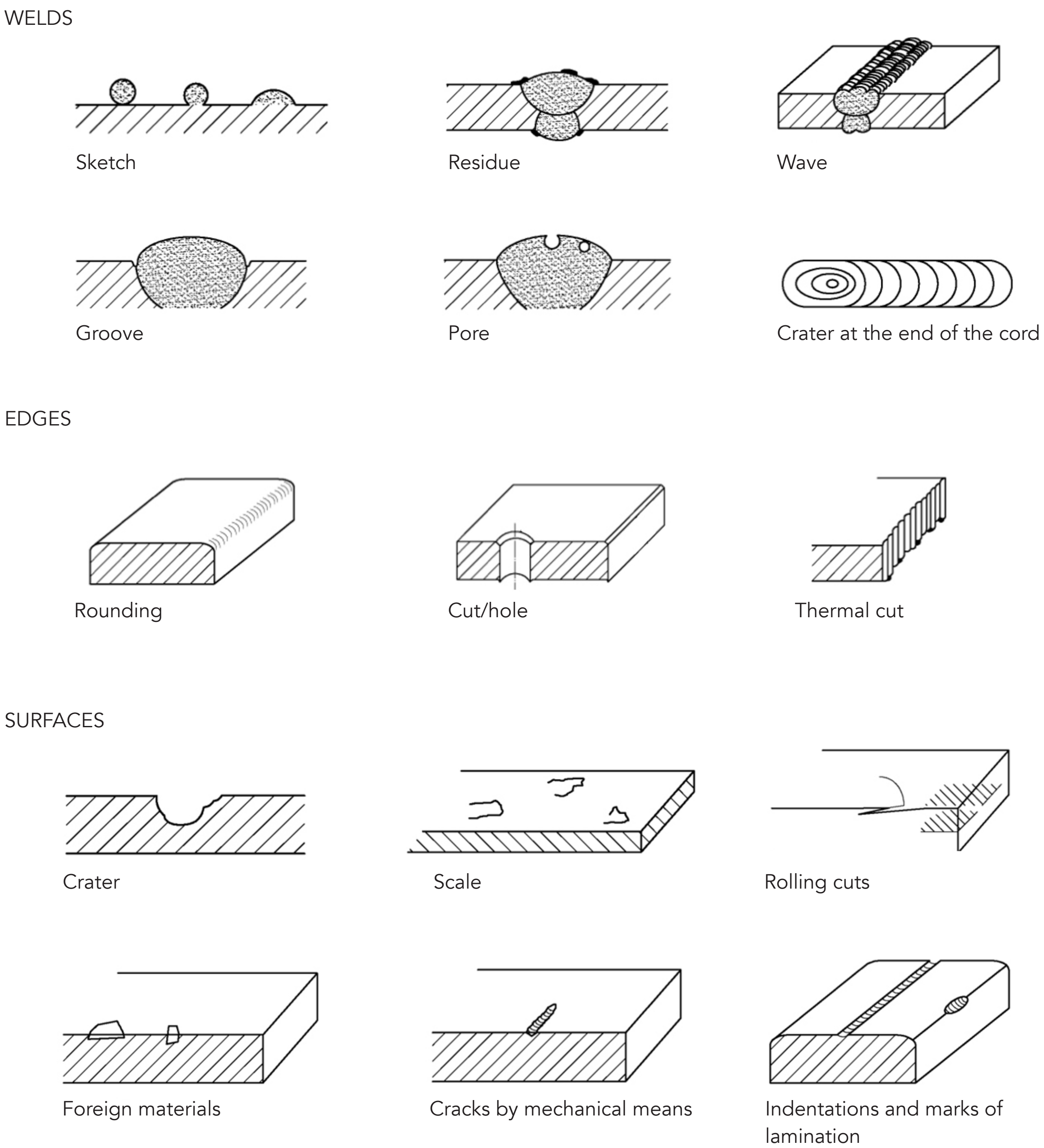
in the standard (ISO 8502-12:2003, "Preparation of steel substrates before application of paints and related products-- Tests for the assessment of surface cleanliness--Part 12: Field method for the titrimetric determination of water-soluble ferrous ions").

When the surface preparation is done by blasting, it is necessary, before making the protective treatment, to evaluate the characteristics of surface roughness of the substrates. The employed methods in accordance with the standard ISO 8503-1-5, "Preparation of steel substrates before application of paints and related products – Surface roughness characteristics of blast-cleaned steel substrates" are:

- determination of the surface profile using a tactile-visual comparison of ISO standards: reference is made to the samples "G" when the blasting takes place with an irregular grain abrasive, and to the samples "S" when blasting is done with an abrasive spheroidal particle size; the standard provides comparative values that allow you to categorize your listing in small, medium or large; the comparison is done using a magnifying glass (with a maximum increase of up to 7 times), which can easily be used on the building site, by subjecting to contemporary magnification the standard ISO and the sample surface;
- determination of the surface profile by using a light microscope: the highest points come into focus and then the lowest points determine the distance; the procedure is repeated 20 times in different fields of vision at a minimum distance of 5 mm from the edges of the element and then the mean of the distances is calculated; the validity of the method is limited only to an average peak-to-trough distance between 120 μm and 200 μm, the method is also used to calibrate the ISO samples;
- fingerprint method on adhesive tape: for the determination of the surface profile at the building site, tape is applied to the element; the tape is made with a polyester layer of uniform thickness (50 μm ± 2 μm) with a polymetric deformable micro-foam; it undergoes pressure (using a plastic rod with ball) and it causes a contraction up to 25% of its original thickness; by removing the tape on the cast of the surface, it is possible to take measurements (peak-to-trough) through an electron microscope; the tapes on the market allow for the measurement of profiles that have a peak-to-trough distance from 20 μm and 115 μm;
- determination of the surface profile by using a stylus instrument: The high points and the low points are measured through the vertical displacement of the instrument with the stylus, which determines the maximum depth in 10 different areas of the surface. Considered with longitudinal displacement; the range of validity of the method is limited to elements having a maximum average depth from 20 μm and 200 μm; the method can also be used to calibrate the tactile-visual comparison of ISO standards.

In general, the value of roughness that is considered optimal (expressed in peak-to-trough distance) is in the range of 30-50 μm.

Furthermore, especially in the case of reuse for elements that may have already experienced one or more cycles of life, if after the preparation treatment, the opportunity to make a painting treatment, is considered, visual analysis should be carried out with reference to the state of welds (if any), edges and surfaces. In particular reference to the welds, sketches, residue, waves, grooves, pores and craters at the end of the cord should be evaluated. With reference to the edges, the rounding, any cuts or holes and the thermal cut should be evaluated. In referring to the surfaces, the presence of craters, scales, rolling cuts, foreign materials, cracks by mechanical actions and indentations and laminations marks as expressed within the standard ISO 8501-3:2006, "Preparation of steel substrates before application of paints and related products – Visual assess-



ment of surface cleanliness----Part 3: Preparation grades of welds, edges and other areas with surface imperfections".

With respect to the assessments, the present preparation level and any level to reach should be scanned (P1: slight preparation, P2: rigorous preparation, and P3: very strict preparation). Preparation treatments can be summarized as indicated in the above table, not only depending on the type of existing surface (raw or lacquered), but also depending on the convenience of realization (in the factory or on site) and the level of achieved preparation.

When the preventive treatment does not take place immediately after preparation, in order to prevent degradation of the element, it is possible to apply temporary treatments consisting of prefabrication primer[8], cards/ adhesive films, removable coatings and other materials that can be easily removed. The most widely used prevention treatments are described below.

- Painting: the type of painting to apply is chosen depending on the application environment (corrosion category), on the level of surface preparation and on-durability[9]. The paints can be classified into:
  - solvent-based paints
  - water-based paints
  - paints without solvent.

  There are reversible paints where the film dries by evaporation of the solvents without changing form. Therefore, at any time, the application of solvents produces the reverse mechanism and irreversible paints in which the film dries by evaporation of the solvents and by chemical reaction or coalescence, belong to the latter type: paint with air drying (oxidative hardening), paint based on water (one component) paint with chemical hardening and paint hardening by moisture.

Preparation treatment:	Location of realization		Effectiveness
	Plant	Site	
Cleaning with water			Oily substances
Cleaning with vapour			Oily substances / varnishes
Cleaning with emulsifier/ alkaline products			Oily substances / varnishes
Cleaning with organic solvents			Oily substances / varnishes
Cleaning with chemical conversion			Oily substances / varnishes
Chemical pickling			Varnishes
Acid pickling			Varnishes / processing residues / rust
Manual abrasion			Varnishes / processing residues / rust Corrosion levels B, C, D - preparation St 2
Motorized abrasion			Varnishes / processing residues / rust Corrosion levels B, C, D - preparation St 3
Centrifugal sandblasting			Varnishes / processing residues / rust All corrosion levels- preparation Sa 3
Sandblasting with compressed air			Varnishes / processing residues / rust All corrosion levels- preparation Sa 3
Sandblasting with recovery with aspiration			Varnishes / processing residues / rust Corrosion levels A, B, C - preparation Sa 2 ½
Sandblasting with wet compressed air			Varnishes / processing residues / rust All corrosion levels- preparation Sa 3
Sandblasting with compressed air and wet abrasive			Varnishes / processing residues / rust All corrosion levels -preparation Sa 3
Wet sandblasting with very fine abrasive			Varnishes / processing residues / rust All corrosion levels- preparation Sa 3
Sandblasting with pressurized liquid			Varnishes / processing residues / rust Corrosion levels A, B, C- preparation Sa 3 Corrosion level D - preparation Sa 2 ½
Cleaning with flame			Processing residues / rust All corrosion levels- preparation Fl

When using paints based on synthetic resins and metallic zinc, the treatment is called "cold galvanising." This paint is commonly used as under painting. A layer of paint of another type of finish, which gives the colour to the element, is placed over the "cold galvanising". Durability[10] can be divided into three classes: low (L) from 2 to 5 years, average (M) from 5 to 15 years, and high (H) over 15 years and also it is dependent on the category of corrosiveness from the environment. The stability is also influenced by several factors such as the type of paint, the structural design, the condition of the element before preparation, the effectiveness of surface preparation, the quality of treatment, the environmental conditions during application and the exposure conditions after application.

The coating can be applied in the factory or in the building site. The standard[3] recommends applying at the plant, as it has benefits in terms of temperature and humidity control of application, a better result, and minor dust contamination extraneous to the process. However, it has the disadvantage of limiting the size of the elements, there is a risk of damage during transport or assembly and there is possible contamination for the last coat of paint. Otherwise, the application of painting at the building site is strongly influenced by weather conditions that affect the durability and effectiveness of the treatment. The application has to be made as indicated the product data sheet, which proves that the dry film thickness is not less than 80% of the wet film (except different prescriptions).

The application should be done in favourable weather conditions and with a temperature higher than 3°C. The methods of application are by brush, roller, or spray (with low air pressure, without air, with medium pressure air and electrostatically).

The verification of the correct execution of the painting is done by visual analysis of uniformity, colour, opacity, overlay, defects of the roughness, air bubbles, stains and holes, cracks and through specific instrumentation for the measurement of dry film thickness, adhesion and porosity.

- Galvanizing: before applying this treatment, the surface must have a high level of cleaning (Sa3). There are many kinds of galvanising. The most used is the galvanising through the immersion of the element in tanks (usually with size 12.5 m x 3.0 m x 1.50 m) containing molten zinc at 450° C for a time (between 1.5 and 5 minutes) proportional to the size of the element and its thickness. If required, the element is cooled in a water tank; the dive in and out have to occur in the same direction to ensure uniformity of zinc coating. Treatment in tanks limits the size of the elements which need to be adapted already in the planning stages for this treatment. The thickness of the zinc layer depends on the size of the structural element, usually between 50 and 100 μm. In addition, all the elements employed in the same building must have the same thickness, otherwise the difference in cooling could cause deformation. regard to uniformity of zinc coating on the individual element (edges, corners, etc.). The application of hot-dip galvanising on hollow elements hermetically welded (like tube structural profile) needs ventilation holes to prevent the explosion of the element due to expansion caused by the air temperature. The galvanising has to be made in the factory and it is preceded by degreasing and pickling treatments designed to prepare the surface.
  In case of difficult application of hot-dip galvanising, spray galvanising can be applied. The metal zinc in powder or wire form is heated up until fusion, and then it is sprayed through a gun using compressed air (5.5 bar). This method, besides having very high costs, has the limitation of not ensuring the uniformity of the zinc layer and it can also present a porous structure. Therefore, it requires the application of a subsequent polymer layer.
  The galvanising spray can be made both in plant and at the building site, provided that it complies with the conditions for application as required by the standard ISO 14919:2001, "Thermal spraying--Wires, rods and cords for flame and arc spraying--Classification--Technical supply conditions." The average distance of the gun from the element has to be between 15 and 25 cm, and the deposition of the metal must be through cross movements. Durability is on average more than 20 years and it is linearly dependent on the thickness of the zinc coating.
  The appearance of zinc varies depending on the composition of steel, silicon and phosphorus content (% Si, % P).
  Unlike the standard ISO 14713-2:2009, "Zinc coatings--Guidelines and recommendations for the protection against corrosion of iron and steel in structures-Part 2: Hot dip galvanising," provides a forecast of the outcome for each composition, in order to comparatively assess the correct implementation of treatment.
  In the case of reuse, through this comparison, it is possible to identify the composition of steel in order to define its properties and to identify appropriate treatments also depending on environmental conditions and the usage class. It is also preferable to reuse of steel that has a category A or B as a thicker coating has a high risk of brittle fracture.
- Mixed systems: they exploit the combination of the characteristics of the finishes and cladding systems. Galvanisation is first made, and then it is covered with a suitable paint, which increases the variable duration of protection between 1.2 and 2.5 times[11].

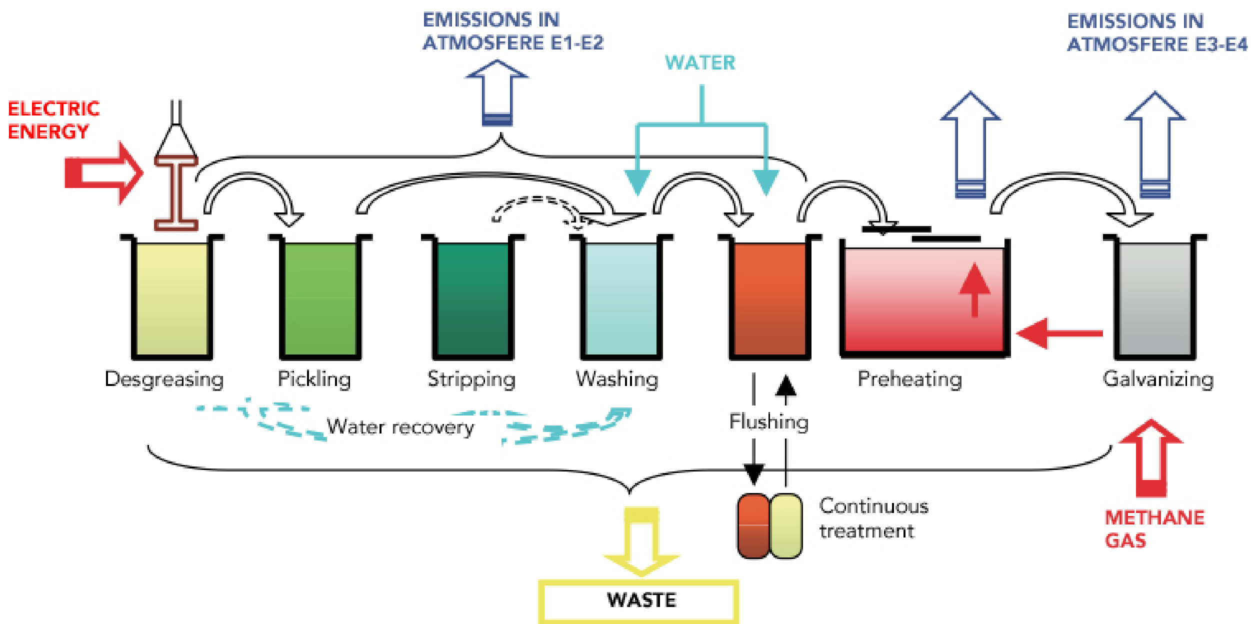
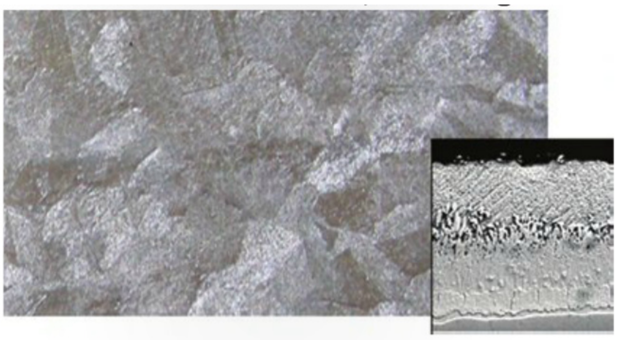
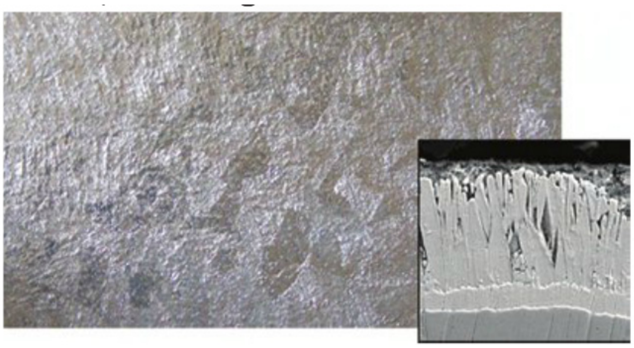


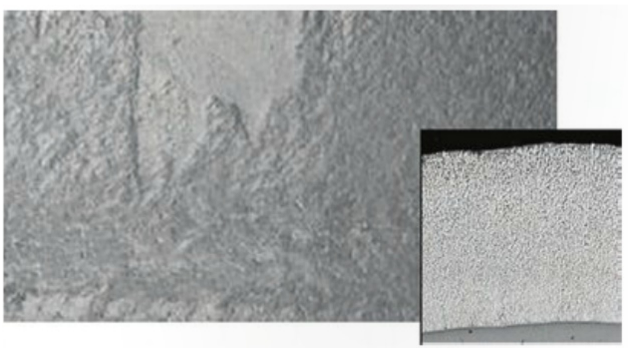
Fig. 5 _Hot dip galvanizing process



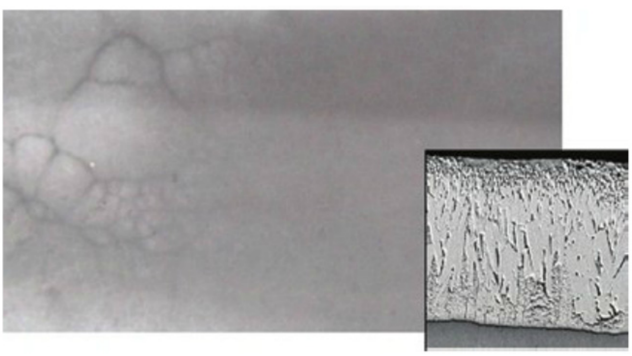
Category A - Si≤0,04%; P<0,02%



Category B - 0,14%<Si≤0,25%; P<0,02%



Category C - 0,04%<Si≤0,14%; P>0,025%



Category D - Si>25%; P<0,02%

Fig. 6 _Surface appearance and microscopic section of galvanizing steel according to the category

Typically the hot-dip galvanising is combined with powder coating, using intermediate surface preparation treatments. Painting in contact with atmospheric agents and corrosive environment protects the layer of zinc. The latter begins to deteriorate, in fact, only after the outermost layer of paint is no longer able to protect due to decay.

In the case of reuse of an element that presents the galvanising in good condition, i.e. without the occurrence of corrosion, it is possible to evaluate the application of a coating system in order to increase the durability depending on planned reuse and environmental conditions. If, however, there is the intention to reuse an element that is galvanised, which is not in good condition, according to the level of corrosion present, it has to be evaluated whether to make a localised restoration of the galvanised layer in the corroded points (through localised cleaning and localised spray galvanising), and then to apply a protective coating on the entire element or if removing the present galvanising and apply a new protective treatment through mixed systems. While in the first case, the intervention can be performed both in the factory and in the construction site, in the second case it can only be done in the factory, because the removal of zinc requires acid pickling.

The use of mixed systems is influenced also by aesthetic reason. Through painting, it is possible to give the galvanised element variable colorations.

Only in some cases, when it is necessary to act on elements of smalerl size and weight, electroplating and metal plating systems are also used.

7.3 _ Dimension, shape and mass tolerances

The reuse of steel elements requires, in the first place, the evaluation of allowable tolerances, in order to verify the minimum conditions for structural use. The legislation establishes the minimum conditions depending on the type of profile (UPN, IPE, etc.). The reuse is made with elements already marketed. For this reason, it is possible to neglect the monitoring of dimensional deviations and concentrate the attention on the variations of mass and shape.

The mass variations depend on the degradation level and on the portion of the profile affected by corrosion, which can be evaluated as previously described.

The shape variations, however, are the result of plastic deformation of the profiles due to the loads and the forces present in their previous use. Therefore, we have to evaluate the straightness, the curvature, the perpendicularity, and the symmetry of the profile. In particular, the application of systems with steel rods may have caused the plastic deformation of the profiles that are often used in coupled conformation.

Evaluations can be made through the use of measurement systems:

- dial gauges and electronic scales: the dial gauge consists of two circuits on the same axis, an iron core connected to a non-metallic finger moves axially inside the windings; the finger is related to the measuring axis and, when the latter is moved, a differential transformer induces equal and opposite tensions in secondary circuits allowing the measurement; the electronic scales consist of a pendulum suspended vertically, whose deviations are measured through a differential circuit similar to that of the dial gauges;

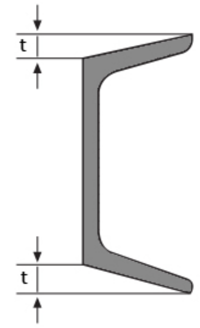
- coordinate machines: a probe is moved according to a set of axes on each point of measuring volume, which detects the coordinates, through which it is possible to define the dimensional and geometric characteristics of the element;
- laser machines: everaging the straightness of the laser in the vacuum; in double-beam systems, two laser beams invest the element and by the measurement of two distances with constant separation, it is possible to calculate the position, angular deviation and the straightness.

Dial gauges, electronic scales and laser machines can be used in the building site.

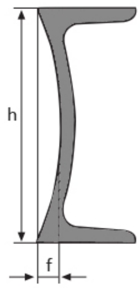
7.4 _ Methodological- operative procedure for the reuse

The reuse of a steel element needs an operative procedure that must be assumed during the planning phase of renovation/regeneration of the building in order to ensure the integrity of the elements during demolition and, at the same time, decrease the time and costs of the intervention. The type of security system, the section and the length of the elements, the type of connections and their reversibility have to first be analysed. Then it proceeds to the dismantling of the system (which generally takes place in phases parallel to reconstruction/consolidation). It has to be programmed to keep the length of the elements and remove only the welded parts that have a geometrical shape that it is difficult to reuse (for example, welded joints with right angles). The waste is separated into homogeneous categories on site and can be salvaged for recycling.
When assessing the compatibility between the available elements and the type of planned intervention, it is possible to make a first selection, aimed at identifying elements

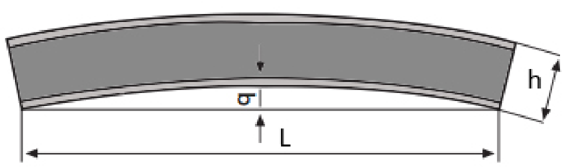
UPN PROFILES



Outside square
≤1 mm.

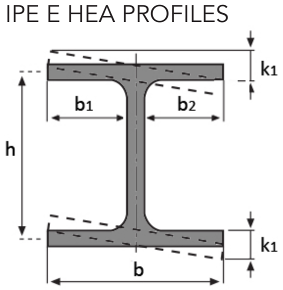


Curving of web plate
h< 100 mm, f < 0,5 mm
100 <h<200 mm, f < 1,0 mm
h > 200 mm, f < 1,5

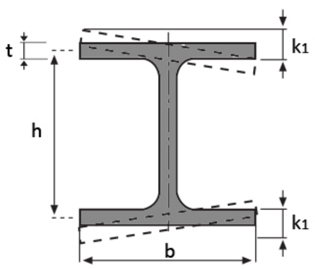


Error of straightening
≤ 0,0015 L (measured in the plane of web plate and on the whole length L of the profile)

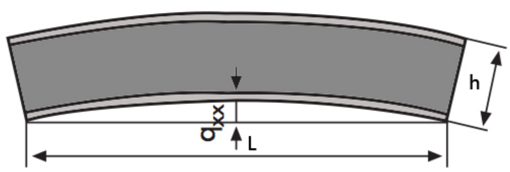
IPE E HEA PROFILES

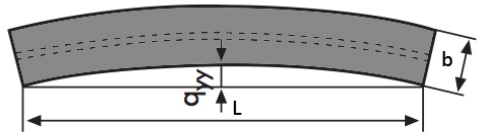


Tollerance of perpendicularity (outside square)
b≤110 mm,
k+k1= 1,5 mm
b> 110 mm,
k+k1= 2% di b



Tollerance of simmetry
If t< 40 mm
b≤110 mm, e=2,5 mm
110<b≤325 mm, e=3,5 mm
b>325mm, e=5,0 mm
If t ≥40 mm
110<b≤325 mm, e=5,0 mm
b>325mm, e=8,0 mm
where e= (b1-b2)/2





Straightening
80<h≤180 mm, qxx=qyy=0,3% di L
180<h≤360 mm, qxx=qyy=0,15% di L
360 mm>h, qxx=qyy=0,1% di L

Fig. 7 _ Tollerances of the profiles UPN, IPE and HEA

that for characteristics (type of profile, geometry, dimensions, weight, capacity, type of compatible connections, etc.) are best suited to meet the design and technological needs in the regeneration intervention. Then it proceeds to the evaluation of geometric tolerances, to calculate the potential reusability of elements for structural use.
If these tolerances are not satisfied, it is possible:

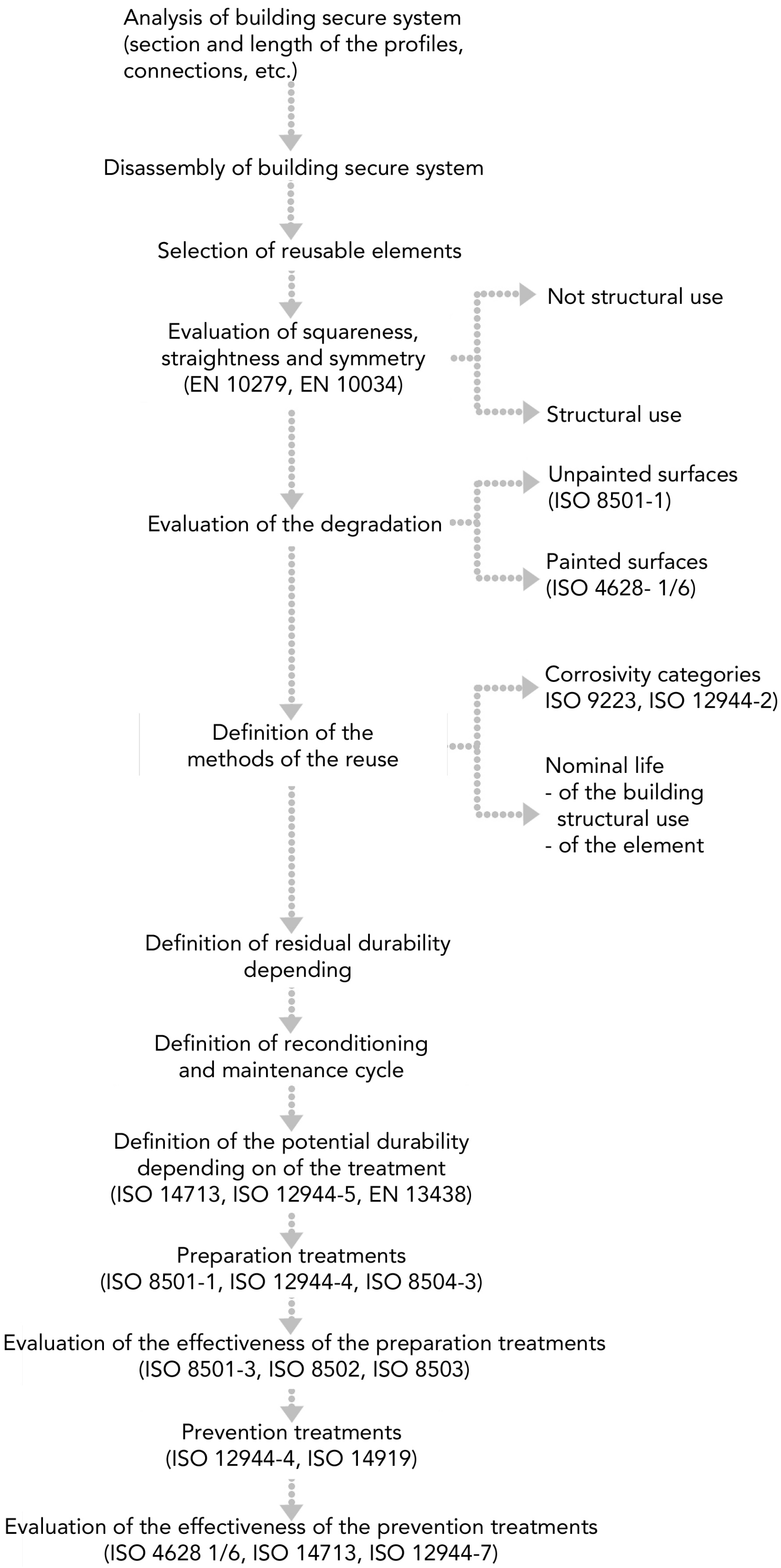
- to use the element for non-structural use,
- to deliver the element to the establishment and to perform straightening operations,
- in case of out-of-square and non-symmetry and if it is a localized deformation, to delete the portion of the element that does not meet the dimensional tolerances.

Once defined the type of use (structural or non-structural), reconditioning operations designed to reduce the problems of tolerance, the level of degradation present and the type of impurity (oils, paints, rust, slag by rolling or welding, etc.)[12] are also determined.
Next, it is defined in detail how reuse and the expected life for the element in case of non-structural use and nominal life of the structure in case of structural reuse.
According to the NTC 2008, in case of structural reuse, it is necessary to consider the following nominal lives:

- provisional/ temporary structures, structures in construction phase: Vn ≤ 10 years,
- ordinary works-bridges-infrastructures and dams: Vn ≥ 50 years,
- great works- bridges-infrastructures and dams with big size or strategic importance: Vn ≥ 100 years.

After these considerations, the corrosiveness of the environment[13] where the elements will be reused has to be detected.
The following table illustrates the relationship between corrosivity, environments and loss of thickness or mass.
Therefore, it is possible to calculate the mass and loss of thickness, to predict the evolution of the element's degradation and act proactively via an appropriate sizing of the elements and the application of preventive treatment.
According to the current degradation, corrosivity categories and the nominal life of the building, it is possible to evaluate the residual durability and to prepare a reconditioning and maintenance plan that ensures the required durability through the selection of appropriate treatments. By taking into account the residual durability, the modes of reuse and predicting the future degradation, as well as defining the timing and manner of maintenance, the engineer will have to decide whether to perform treatments before reuse or to find compatible reuse with the residual durability, which would postpone treatments. The choice of treatment should consider the close relationship between degradation, preparation and preventive treatments. Every preventive treatment requires a specific level of surface preparation, but the latter is influenced by both the mode of treatment and the level of degradation. For example, depending on the type of used paint, the binder,

Class	Loss of thickness (µm/anno) Loss of mass(g/m^2)		Environments	
	Steel with low C	Zinc	Inside	Outside
C1 very low	≤1,3 µm/year	≤0,1 µm/year	Low relative humidity. Heated buildings with clean atmosphere.	Cold or dry areas with very rare rainfall and absence of condensation.
	≤10 g/m^2	≤0,7 g/m^2		
C2 low	1,3-2,5µm/year	0,1-0,7µm/year	Temperature and variable relative humidity and low values of pollution. Unheated buildings where condensation may occur.	Temperate areas with pollution content, cold or dry areas with limited condensate (natural areas).
	10-200 g/m^2	0,7-5 g/m^2		
C3 medium	25-50 µm/year	0,7-2,1µm/year	Production areas with high humidity and pollution (food industries, breweries, dairies).	Urban and industrial environments with moderate sulfur dioxide pollution, coastal areas with low salinity, (SO2 up to 30 µg/m^3 or media presence of chlorides).
	200-400 g/m^2	5-15 g/m^2		
C4 high	50-80 µm/year	2,1-4,2µm/year	Chemical plants, swimming pools, coastal shipyards for boats	Industrial areas with high humidity and corrosive atmosphere
	400-650 g/m^2	15-30 g/m^2		
C5-I very high industrial	80-200µm/year	4,2-8,4µm/year	Buildings or areas with almost permanent condensation and pollution.	Industrial areas with high humidity and corrosive atmosphere (SO2 up to 90 µg / m3 - high level of chlorides).
	650-1500 g/m^2	30-60 g/m^2		
C5-M very high marine	80-200µm/year	4,2-8,4µm/year	Buildings or areas with almost permanent condensation and high pollution.	Coastal and offshore areas with high salinity (SO2 up to 250 µg/m^3).
	650-1500 g/m^2	30-60 g/m^2		


Analysis of building secure system (section and length of the profiles, connections, etc.)
Disassembly of building secure system
Selection of reusable elements
Evaluation of squareness, straightness and symmetry (EN 10279, EN 10034)
Not structural use
Structural use
Evaluation of the degradation
Unpainted surfaces (ISO 8501-1)
Painted surfaces (ISO 4628- 1/6)
Definition of the methods of the reuse
Corrosivity categories ISO 9223, ISO 12944-2)
Nominal life
- of the building structural use
- of the element
Definition of residual durability depending
Definition of reconditioning and maintenance cycle
Definition of the potential durability depending on of the treatment (ISO 14713, ISO 12944-5, EN 13438)
Preparation treatments (ISO 8501-1, ISO 12944-4, ISO 8504-3)
Evaluation of the effectiveness of the preparation treatments (ISO 8501-3, ISO 8502, ISO 8503)
Prevention treatments (ISO 12944-4, ISO 14919)
Evaluation of the effectiveness of the prevention treatments (ISO 4628 1/6, ISO 14713, ISO 12944-7)

and the number of layers and thickness, the corresponding durability (high, medium, low) is defined with respect to corrosivity (C1-C2-C-C4-C5) in order to respond to the requirements of the nominal life of the structure and its maintenance plan. For example, in case of a larger element, which does not present problems of dimensional tolerances, with degradation caused by rust of C class that can be reused for structural use in corrosivity category C3, a paint treatment mixed with binder AK and 2 layers of 80 µm and later 5 layers of 200 µm[14] should be used. For the application of this painting, it is necessary to perform a preventive treatment to optimize the reuse of the element. For example, the blasting can be done as it is suitable for the removal of C class rust degradation, which helps it reach a level of 2 ½, preparedness. This makes it suitable for drafting subsequent composite paint as described above. From a decision-making point of view, the preventive treatment is defined before the appropriate preparation treatment is chosen and after from an operational point of view. However, the treatments follow the reverse order. Once the preparation treatment has been performed, we have to check the effectiveness of the treatment in terms of residues of calamine, oxide and contaminants, both in terms of surface roughness and for the state of the welds (if present), edges and surfaces.
Subsequently, it is possible to apply the preventive treatment (painting, galvanising or by mixed systems). The treatment effectiveness has to be evaluated through comparative visual analysis. For reuse, it is desirable to define the level of corrosion and the hypothesis of the reuse with respect to the corrosivity category of the atmospheric environment and to assess the opportunity for a treatment of repair or of total reconstruction of the coating layer.

7.5 _Good practices for construction

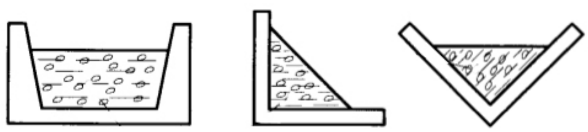
The durability of steel elements can be increased through constructive methods to prevent the corrosive phenomenon. The project, in addition to ensuring the stability of the structure, has to consider all factors that influence the durability: the profile section (with particular attention to the box-profiles), the size and weight of the elements and the structure, the connections, the stiffeners, accessibility, mode of transport, handling and the assembly/disassembly. As a preventive measure prior to assembling the elements, the effectiveness of treatments carried out has to be monitored. For this reason, it is necessary to program a maintenance plan and establish the time schedule for the controls and maintenance interventions. The standard provides measures to prevent the corrosion and depends on the treatment that is performed: for painting we can refer to ISO 12944-3: 1998; for galvanizing we can refer to ISO 1461: 2009 and ISO 14713: 2009.
When the element is protected with varnish, in the effort to prevent corrosion, the following precaution[15] have to be complied:

- accessibility: the steel elements have to be accessible in the realization, testing and maintenance, through the help of auxiliary devices (mobile bridges, walkways, retaining hooks, application guides, etc.) through a sufficient space to work on elements even when they were placed in work (should be considered the minimum space for work equipment) and through additional ventilation holes; if it is not possible to guarantee the minimum conditions of accessibility, a more durable coating system must be used and the thickness of the element should be oversized in order to absorb the risk of corrosion; minimum spaces necessary for the realization are:

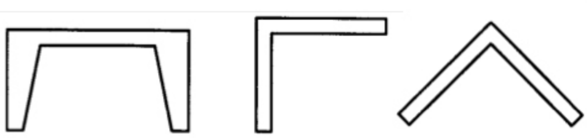
Operation	Dm (mm)	Dms (mm)	A° (°)
Surface preparation with abrasive blasting	800	200/400	60-90
Cleaning with mechanical instrumentation: with needles, polishing/sanding	 250/350 100/150	 0 0	 30/90 0
Cleaning with manual instrumentation: brushing	100	0	0/30
Metal spraying	300	150/200	90
Paint application: pulverization brush roller	 200/300 200 200	 200/300 0 0	 90 45/90 10/90

Dm: size of instrumentation
Dms: size of instrumentation-substrate
A°: angle of application

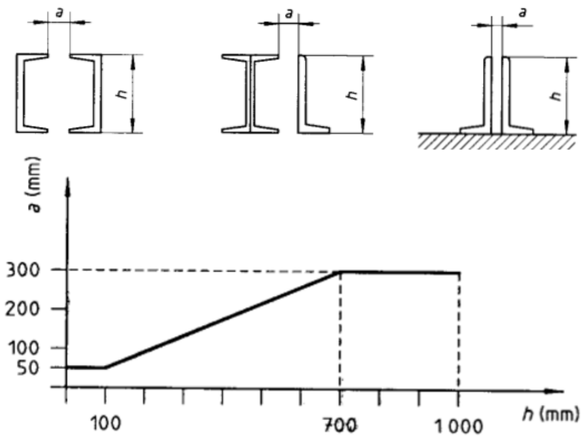
- treatment of interstices: interstices have to be sealed, in highly corrosive environments; the interstices and the contact surfaces have to be filled through seamless welding;
- precautions to prevent sediment and water retention: through the project of inclined or rounded surfaces, the elimination of open sections positioned in such a way as to become containers of water, i.e. with the cavity facing up the elimination of cavities or holes, the drainage and the disposal of water through geometric shapes which create channels or discontinuity;
- edges: it is preferable that the edges are rounded in order to reduce the risk of rupture to the coating and the defects in the edges should be deleted when they are especially sharp;



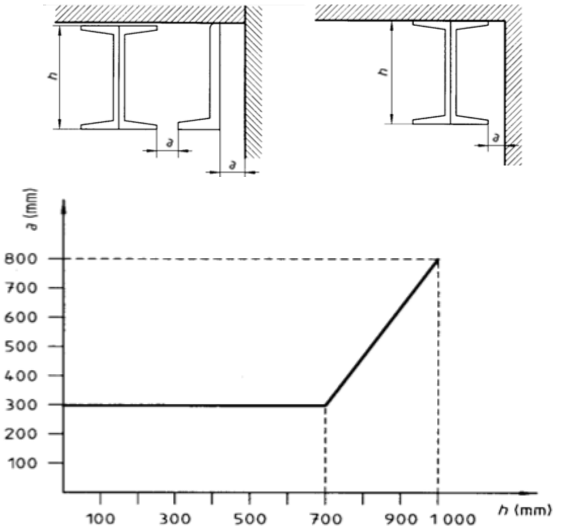
unsuitable



suitable

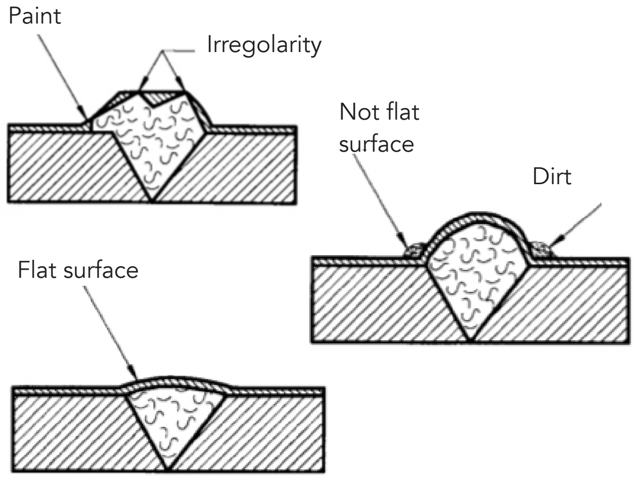


inimum distance between two profiles



Minimum distance between a profile and a surface

- bolted joints: before mounting, the friction surfaces have to be prepared with blasting with a minimum level of Sa 2 ½; bolts, nuts and washers must have the same level of protection;
- boxed parts and built-in components: the surface exposed to corrosion is reduced for conformation, provided that the holes are sealed airtight and watertight and that the connections between surfaces are with seamless welding; this ensures that making sure that water does not remain trapped within the profile;
- carved works: they must have a minimum radius of 50 mm in order to facilitate the application of the coating;
- stiffening elements: the application of stiffening elements must take place by welding in order to prevent corrosion in the voids; the geometric shape has to avoid the stagnation of water and dirt accumulation;
- prevention of galvanic corrosion: when two metals are in contact with a different level of nobility; in particular, when the less noble metal has a much smaller area than the more noble metal, spring washers should not be used because they can cause interstitial condensation; the two surfaces in contact have to be electrically isolated, for example, by coating both surfaces; if it is not possible to paint both surfaces, the coating should be applied at least on the surface more noble, or alternatively, must carry out a cathodic protection intervention;
- handling, transport and assembly: it is necessary to pay attention to the lifting system and the anchor points, as well as the modes of transport, in order to avoid damage to the coating; sealing clamps can be provided;
- welding surfaces: they have to be free by imperfections like cracks, roughness, craters, in order to reduce the risks from dirt accumulation and water, which facilitate the application of a uniform coating.



When the element is protected by hot dip galvanizing, to prevent corrosion, the following precautions[16] have to be made:

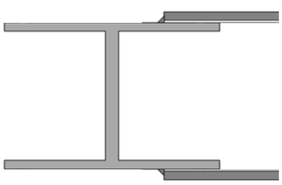
- preparation of vent holes and drainage on the elements before galvanising: the lack of or incorrect drilling, in the case of hollow elements, will cause an explosion; this results in a deformation due to the formation of air pockets that prevent the escape of warm air under pressure; this precaution has to also be taken into account in the case of galvanising of hollow profiles welded on plates; even in the case of open profiles, drilling must be queried in points which can form cavities with air trapping in the immersion; ventilation holes have to be made, which must take into account the aesthetic and structural characteristics of the element; the standard also provides the minimum size of the holes depending on the size of the section;
- elimination of surface defects: the galvanising accentuates the present surface defects that should be eliminated in reference to the surface of the element, and to any welds; besides purely aesthetic imperfections, the presence of defects (rolling slivers, cutting or drilling burrs and thermal cuts) causes a timely variation of the thickness to the zinc coating, which reduces the effectiveness of treatment and facilitates the occurrence of localized corrosion (particularly damaging in the edges subject to greater fragility of the coating);

also, sagging rust may occur, due to the release of salts or acid trapped in the cavities or interstices;

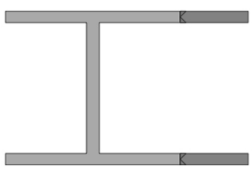
- stiffening elements: the plunged steel has a thermal expansion indicative of 4-5 mm per linear metre; it is appropriate in the case of large elements to prepare stiffening brackets in order to contain distortions; in case of reuse of steel elements, if welded stiffeners are already present along the element, before proceeding to an eventual galvanisation, the presence of drainage holes has to be checked in corner points between the element and the stiffening; alternatively, stiffeners with minor dimension to the height of the profile may be used;
- connections: the welding of elements should be performed before galvanising, by choosing a welding mode that reduces the presence of interstices. Unlike the case of bolting, it is appropriate prior to galvanising and, only subsequently, to unite the elements, because the reversible connections have parts with interstices that affect the galvanisation. In each case, the holes for subsequent bolting have to be made prior to galvanising. It is also improper to weld elements that have already been galvanised, because with the high temperatures of welding, the zinc coating emits zinc oxide that adversely affects the possibility of connection and endangers the health of the operator. Finally, the assembly must take place between elements that have undergone the same treatment to avoid a different degradation during the life of the product. In fact, the less durable that one of the elements is, triggers corrosive processes in the elements, which would otherwise have a greater durability. It is not appropriate to assemble already galvanised elements with non-galvanised elements.

In the case of reuse of an element, as well as the degradation and the environmental conditions of reuse, it is appropriate to optimise the durability through construction methods also evaluated through the comparison to the reversibility of the system.

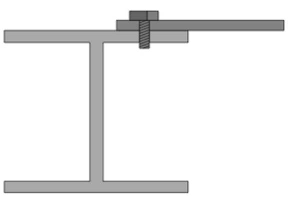
For example, in reference to the protection of the interstices, the legislation favours the welding connection to prevent corrosion, contrary to ensuring the reversibility of the system that is encouraged by the connection with bolting. Therefore, the technician must choose the type of connection referenced to the environmental conditions, the preventive treatments and the nominal life of the building. The temporary or permanent nature of the building significantly influences this choice. In fact, if the nominal life is less than or equal to 10 years, it will be more convenient to use reversible connections, which enables us to predict in a limited time, the hypothetical reuse of elements. Otherwise, if the building has a nominal life greater than 10 years, the assessment must be made by taking into account the environmental conditions and the speed of deterioration that the elements undergo, i.e. taking into account the influence of interstices on the corrosion rate. The evaluation should be made to consider the specific period of time that the impact of maintenance interventions (welding or bolting) will have and add it to its end-of-life impact. However, the end-of-life scenarios of each element have to be programmed, already in the planning phase, to take into account the impact of welds on the mode of reuse and consider the convenience of cutting the welded points or recycling the whole element.



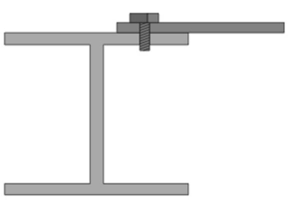
Incorrect welding
for the presence of interstices



Correct welding
operative steps:
1° welding 2° galvanizing



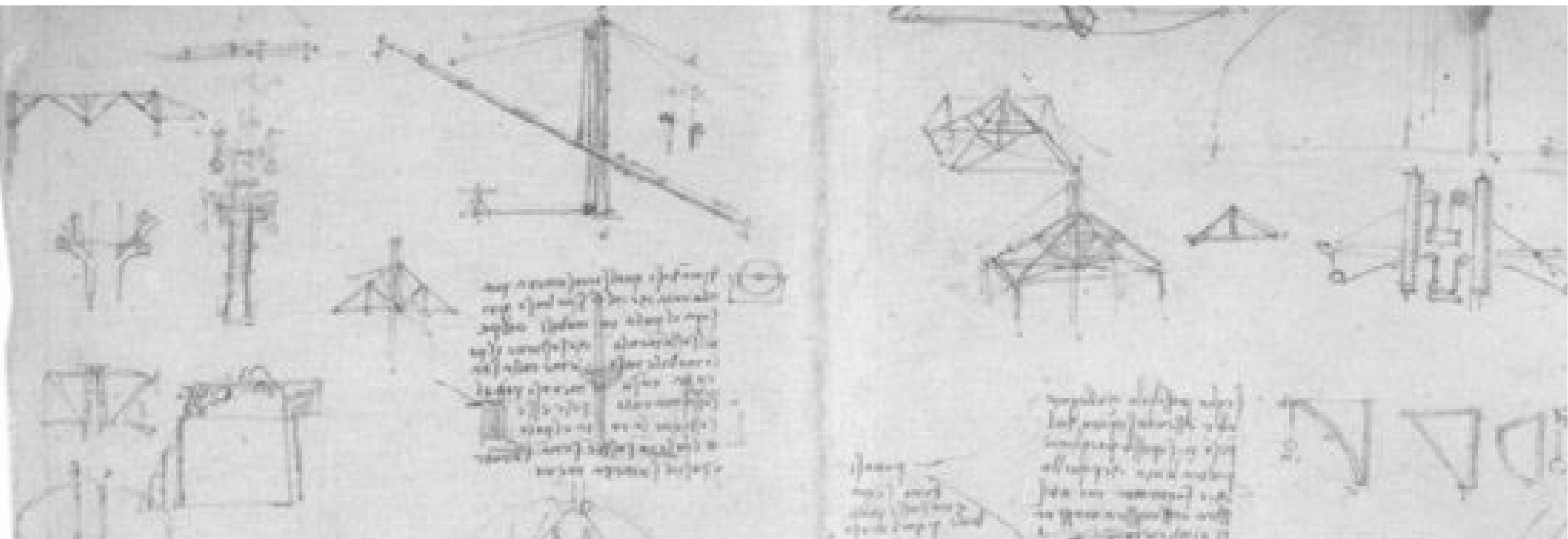
Incorrect bolting
operative steps:
1° bolting, 2°galvanizing



Correct bolting
operative steps:
1° galvanizing, 2° bolting

NOTES

1. *Tectonica n.18, Rehabilitación, "Intervenir en arquitecturas portantes", Ramos Galino F.J., Ramos Sanz A.*
2. *The size of the comparative images related to levels of corrosion are 15x14 cm*
3. *ISO 12944-5: 2007, "Paints and varnishes -- Corrosion protection of steel structures by protective paint systems -- Part 5: Protective paint systems."*
4. *Breevort G.H., Roebuck A.H., "A Review and Update of the Paint and Coatings Cost and Selection Guide", Corrosion Performance, 1993*
5. *EN ISO 8504-3: 1993; "Preparation of steel substrates before application of paints and related products -- Surface preparation methods -- Part 3: Hand- and power-tool cleaning."*
6. *ISO 8501-1: 2007, "Preparation of steel substrates before application of paints and related products -- Visual assessment of surface cleanliness -- Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings."*
7. *It refers only to the tests that can be performed on site. For tests that have to be performed in a laboratory/plant, please refer to the indication of the legislation. Also, the verification of the presence of salts, dust and grease is usually made when the element must resist corrosion in high-risk conditions (immersion in water, and contact with the ground). In other cases, a visual analysis is done exclusively.*
8. *Application by spraying a uniform coating (15-30 μm dry film) after abrasive blasting at speeds of 1-3 metres per minute – ISO 12944- 5:2007.*
9. *The standard ISO 12944-5 provides reference tables with case history, which allow the choice for the type of paint, and to locate the required thickness, and number of layers, according to class of corrosivity and required durability.Also, in case of temporary treatment for prefabrication primers, it is also possible to evaluate the compatibility with paint overlay.*
10. *ISO 12944-4: 1998 "Paints and varnishes -- Corrosion protection of steel structures by protective paint systems -- Part 4: Types of surface and surface preparation."*
11. *Schulitz Sobek H., "Atlante dell'Acciaio", UTET, Torino, 1999, pag. 110*
12. *ISO 8501-1 2007 for unpainted surfaces e ISO 4628 1-6: 2003 for painted surfaces*
13. *UNI EN ISO 9223: 2012, "Corrosione dei metalli e loro leghe - Corrosività di atmosfere - Classificazione, determinazione e valutazione."/ UNI EN ISO 12944-1-8:2001, "Pitture e vernici- Protezione dalla corrosione di strutture di acciaio mediante verniciatura."*
14. *UNI EN ISO 12944-5: 2008, "Pitture e vernici - Protezione dalla corrosione di strutture di acciaio mediante verniciatura - Parte 5: Sistemi di verniciatura protettiva.", Annex A.tavola A.1., Sistema n.A1.05*
15. *ISO 12944-3:1998, "Paints and varnishes -- Corrosion protection of steel structures by protective paint systems -- Part 3: Design considerations."*
16. *ISO 1461:2009, "Hot dip galvanized coatings on fabricated iron and steel articles -- Specifications and test methods" - ISO 14713:2009, "Zinc coatings -- Guidelines and recommendations for the protection against corrosion of iron and steel in structures".*



PHASE 5_ Experimental project phase. Endogenous and exogenous reuse in L'Aquila.

The fifth phase consists in an experimental project considering the city of L'Aquila.
The sustainability of reconstruction is tied *in primis* to the attention placed to preserve the integrity and correct separation of materials in the demolitions. *In secundis*, it is tied to the integration between local production and reuse of materials in building restoration projects or in the structures functional to them.
The materials/components, as characterized above, are used for defining constructive systems with a high degree of reversibility and flexibility that can be used, through changes of functional layers to define buildings for supporting the reconstruction.Specifically, the elements resulting from selective demolitions, can be used in same yard for reconstruction (endogenous reuse) with temporary or permanent function, or outside for temporary construction serving the community (exogenous reuse).
The temporary endogenous reuse is aimed at the preparation of site facilities providing, according to the type of the elements, the construction of scaffolding or construction services (offices, dressing rooms, etc.).
The elaborate theories are tested by assuming the reuse of materials arising from safety systems put in place at the Civic Museum of Santa Maria dei Raccomandati (AQ) for the construction of site facilities in a common area that can be used for the reconstruction of the nearby aggregates.
The permanent endogenous reuse; however, consists in the stable insertion of components in the reconstruction project. Through schemes, we describe the hypothesis aimed at improving technological or structural systems of the building where the reconstruction phases of processing, the type of reused elements and possible variations are identified.
The exogenous reuse, instead, is aimed at building structures serving the community, thanks the definition of building systems in order to respond to varying needs by integrating elements that derive from selective demolitions with materials produced in the local supply chain. One of the possible applications consists of the construction for higher efficient housing modules that guarantee comfortable conditions comparable to those of stable houses, which can be used to accommodate the residents of the buildings, where the recovery interventions are being made.

8 _ THE TERRITORY OF L'AQUILA: HYPOTHESIS OF DEVELOPMENT

8.1 _Promoting the local supply chain

The environmental methodology is founded on the control and evaluation of complex relationships in a multidisciplinary perspective that analyses the system as a whole with the aim to identify sustainable models of specific application, which aim to achieve environmental balance.
Each territory, evaluating its specificities and resources (at a cultural and productivity level), on the basis of international guidance, identifies the priority policies of development and establishes the modalities of implementation and dismantling.
The local supply chain is a set of production-distribution-consumption configurations that help to reduce the economic and environmental costs by reducing the number of stages and the development of the same in a limited territory. The impact of the transport decreases both from the place of sourcing of raw materials to the place of production and by the latter to the place of sale and product use.
The strong link of this supply chain with the territory encourages the promotion of the resources present in it and the development of local economies that encourage economic well-being and promote the direct relationship between producer and consumer.
Therefore, the concept of the short supply chain involves three dimensions: geographical proximity, which measures the physical distance between producer and consumer, the social proximity that introduces a modality of communication between producer and consumer and the economic proximity, which guarantees the development of the process in the territory.[1]
The short supply chain today collides with the effects of globalisation, with the presence of markets without borders, where the relationship with the place is lost in the uniformity and standardisation of the products.
In the construction we are witnessing the homogenisation of the construction techniques and the materials related to them, in particular to the use of reinforced concrete and steel (innovation and abuse of 20th century) that have resulted in urban agglomerations without recognition.
The relationship between being ordinary and being anonymous has, in fact, matured in the pre-industrial era as a result of the standardisation of components and factory elements.
The introduction of the "machine for living", the serial reproduction of the building organism, on the one hand responded to the post-war shortages of buildings and, on the other hand, has disrupted the relationship with the place. The use of new materials combined with the simplification of transport has introduced a new way to build, which is not conditioned by the effective availability of the material in the territory, apparently, universally valid, but it is ordinarily impersonal.
A constructive ordinariness that in support of a standardised simplification has forgotten the specificity of the territory and the identity of its users.
The development of local supply chains and their strong ties with the territory is set up as an instrument of return and evaluation of the identity of the place thanks to its potential and excellence. It needs to rethink the construction industry in terms of function for the resources actually present in the territory, which make the architecture recognisable through the choices of materials, technologies and techniques that minimise the environmental damage and optimise economic spending. By making the ordinary architecture of a specific place recognisable through the implementation of traditional constructive techniques and the enhancement of materials/components that come from the territory and return to it, it is possible to contribute to the development of identity in the territory. Therefore,

the local supply chain has a decisive role in overcoming the anonymity that involves the post-war building, which is also a means to overcome the economic crisis and the depopulation of the smaller villages.
The reduction of impact of transport from the sustainability of the local supply chain also involves a change of conception in the industrial process. Traditionally, the latter subtracts raw materials from the environment and returns waste and scrape, according to an open cycle of input/output that produces numerous amounts of environmental damage. In particular, the construction sector, as previously illustrated, contributes significantly to the production of waste. The development of a local supply chain that comes from the territory and arrives to the territory according to a closed cycle model, actually, contributes to sustainable development. Thanks only to the determination of confined areas for action, even if perfectly integrated, it is possible, in fact, to create an exchange network between the predominant centrality and to implement strict control at all stages of the process, which ensures the achievement of the identified objectives.
The closed cycle model transforms the final product of a life cycle, i.e. the waste, in the initial matter of a new life cycle, according to a system present in nature that does not produce waste, but simply creates repeatable closed cycles that feed in progression. As traditionally understood, this conception also brings with it a transformation of the resource concept.
The resource is defined as "any sources or means serving to provide help, assistance or support especially in situations of necessity" (Treccani) and as "the available means that can build a source of income or wealth" (Zanichelli). When discussing the territory resources, a person generically refers to the resources coming from nature or from human intervention on nature. Instead, from a development perspective of closed cycles of matter, the wastes of a cycle are a resource for the cycle that derives from it, because they produce a gain in economic and environmental terms. The concept of waste and the one as a resource are, therefore, a contact point for positive impact on the territory.
Therefore, the creation of a local supply chain that enhances the waste product resources in the same territory, is an extremely sustainable operation, as it combines the geographical, economic and social proximity benefits, with the reduction of environmental impact caused by the slightly virtuous end-of-life scenarios related to the same territory. It should be remembered then that the impact of the local supply chain is not universally valid, but that it depends on the configuration and the way in which they are constructed and relate with the involved subjects involved in the territory of reference.[2]
The post-earthquake reconstruction in L'Aquila is an opportunity for the regeneration of the territory through the requalification of the buildings and the development of new leading economies thanks to the implementation of a local supply chain. As previously described, at present, there is a major problem related to the end-of-life scenarios of the materials/components that constituted the systems of safety, with resulting logistical, economic and environmental challenges for the community. These materials from a perspective of implementation of the local supply chain and creation of closed cycles of the matter are a "0 metre" resource. They are the input of a new life cycle, which sees the reuse. They may be reused as elements to be included in the reconstruction project or as components for the realisation of constructive systems, which act as preparation for the supporting structures in the reconstruction (site services, temporary housing, etc.). The assumption of reuse is the selective demolition of the safety systems that guarantees the integrity of the elements and the homogeneity of material.
In their reuse, the materials/components that come from the selective disassembly of safety systems may be integrated with materials that come from the short supply chain of Abruzzo. Such integration allows for the whole process to stay in a local area, which stimulates the market's input and output with new progressive processes.
In Abruzzo, low-tech cycles that enhance the waste can be potentially developed: the stone resulting from the post-earthquake rubble, the sheep wool as a product of animal industry, straw as residue from the harvest of cereals and wood as a product of forest [3, 4].

8.2 _Procedure for reuse

The proposed procedure for reuse includes the introduction of the reuse process for the materials/components that constitute the safety systems within the local supply chain of enhancement of waste in the Abruzzo region.
In particular, the route follows a logical progression where the process of reconstruction is intertwined with the process of reuse of the elements. Once the building under reconstruction is identified, the successive step is to analyse the safety system. The analysis is preventive, namely finalized to determine the characteristics of the system (reversibility and deterioration) and the disassembly modalities that guarantee the integrity of the reusable elements.
The stages of the preventive assessment include:

- classification of the safety systems, identification of their function and the basic elements;
- identification of the materials and their characteristics;
- analysis of the type of connection and the reversibility of the system;
- visual qualitative analysis of the deterioration and identification of the elements that do not have a sufficient residual performance for reuse;
- definition of dismantling methods that depend on the function of reversibility for the connections and residual performance of the elements.

After these stages, we proceed to the progressive dismantling of the safety system.
In most cases, since the safety systems perform to a structural function, the dismantling takes place in a progressive way, with the implementation of the actions for structural reinforcement.
After dismantling, the part of the elements that are analysed through qualitative analysis that have been identified as not satisfying to minimum necessary performance for

reuse are intended to be recycled (when possible), to the recovery of the energy feedstock or to the landfill. Otherwise, the remaining part is subjected to a definitive assessment finalized to define in detail the residual performance, treatments and the reuse potential of the materials.

The residual performance, in fact, can be defined precisely only after the dismantling of the element because of the lack of visibility on all sides when they are at work. Also, it is impossible to measure some basic parameters for the assessment of the deterioration. Consider, for example, the verification of straightness, symmetry, bowing and perpendicularity in the case of steel profiles that cannot be carried out on the installed element.

Likewise, in the case of assessing the wooden elements for structural reuse, even in Italy where it is possible to perform the visual grading of the elements on buildings (UNI 11119:2004 Beni culturali. Manufatti lignei. Strutture portanti degli edifici. Ispezione in situ per la diagnosi degli elementi in opera. --- Cultural heritage. Wooden artefacts. Load-bearing structures - On site inspections for the diagnosis of timber members) as well as present the most restrictive parameters than the visual grading effected with grains condition of visibility of the element, it requires more time and higher costs due to the need to measure the work defects of the elements (needs of crush barriers, use of forklifts, manual relief of defects, etc.).

Therefore, it is believed to make a qualitative assessment of the deterioration when the safety system is still mounted, aimed to identify the elements that definitely do not present sufficient conditions for reuse and that make more detailed assessments of the deterioration and residual performance after dismantling.

The phases of final assessment are:

- analysis of the residual performance through direct measurement on the element;
- identification of the modality potential for reuse of the elements;
- identification of reconditioning operations that the elements must undergo as a function of reuse.

The result of the final assessment allows the engineer to identify a part of the elements that cannot be reused because it does not meet the minimum performance; therefore, they are used for other end-of-life scenarios, which are a part of elements that meet the minimum performance of reuse.

For each element, it is possible to know the performance level at the moment of dismantling, the possible treatments and the achievable potential performance level. This process creates a system of information that makes the possible modalities of reuse available in a specific place and time. Two possible ways of reuse are identified: endogenous reuse and exogenous reuse[5].

Endogenous reuse gradually takes place within the reconstruction site with the progressive dismantling of the safety system. Depending on the type of safety system and the deterioration level, it is possible to identify the following modalities of reuse:

- the insertion of the components in the reconstruction project, aimed at the adjustment/improvement of the structural part, technical implants, technological part and the redefining of internal spatiality (permanent endogenous reuse);
- the predisposition of temporary structures related to the construction of site service, such as scaffolding, offices, canteens, locker rooms, etc. (temporary endogenous reuse).

With permanent endogenous reuse, the performance of the elements must guarantee a durability equal to that of the building in which they are reused and an appropriate maintenance plan must be set up.

Under temporary endogenous reuse, a lower durability is required for the components, but at the same time, it is necessary to use constructive systems characterised by a high reversibility. Temporary endogenous reuse may also facilitate collaboration between the companies in the reconstruction through the provision of site areas to service more buildings, where the site services can be made with the elements that come from the selective demolition of the safety systems from the neighbouring buildings in the same area.

If the materials/components that constitute the safety systems are reused in a temporary way, when their life cycle is completed, the function of the residual performance will again be reused with this function in neighbouring sites or alternately, serve other purposes within the community. After the disassembly, a selection of the components that reach the minimum potential for the reuse will have to be made again and, eventually, they will have to be replace, as the damaged elements may be reached the point of having to be assigned to other end-of-life scenarios (recycling, recovery of the feedstock energy and landfill).

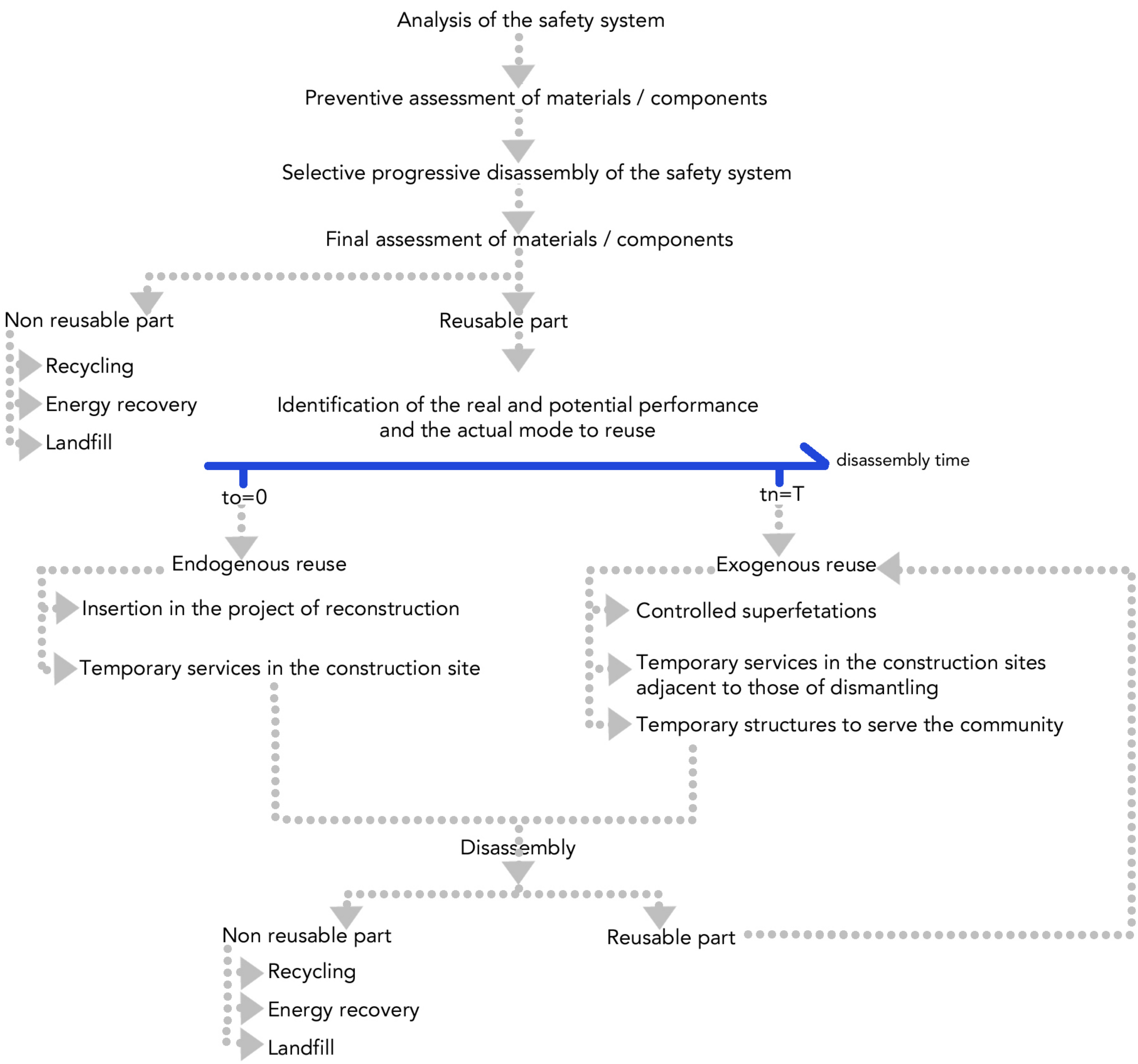
Consider, for example, a construction system that presents a structure of steel bearing and wood panelling.

The two materials have a different durability and function of the environmental class of reuse. At the end of the first life cycle it will likely provide for the reconditioning or replacement of the wooden elements placed in the external covering.

Exogenous reuse, instead, takes place outside the reconstruction site and it is not specifically bound to the progression of selective deconstruction of the safety systems. The components derived from them can be used in the local area (within 100 km) for the construction of temporary structures, which house the functions related to the community (schools, offices, residences, etc.) or for the definition of temporary structures in the service of neighbouring sites where the disassembly occurred.

The collapses occurred diffusely in the buildings in L’Aquila give room to reconstruction interventions through controlled accretions and the critical development of the superfetations that have determined the expansion of many Italian historic centres. In contrast to the “historic superfetations” that derive simply from increasing the family nucleus, the controlled superfetations are constituted as elements of energetic-technological renewal and, at the same time, the spatial variation. Therefore, the resulting building structure must be congruent with the needs from a historical, typological and technological point of view and must present construction characteristics that enable reversibility, in order to allow the adaptation of the build-

ing to the changing boundary conditions.
Compared to the destinations of use, the projected building systems should ensure variable performance.
Therefore, the integration of the materials deriving from the disassembly of the safety systems with the local supply chain materials promotes the compliance of variable requirements and allows to company to overcome any shortcomings in terms of quantity for specific materials. Consider, for example, the failure in quantitative terms between the availability of wooden materials (% minor) and steel elements (% major) resulting from the disassembly of safety systems. In the reuse operations, the wooden elements present a greater variability and flexibility for reuse, and are, therefore, in greater demand. In the case of shortage, they will be integrated through components resulting from the assessment of the regional forests.
Similarly, the absence of reusable materials for insulating purposes, will be compensated by the integration of sheep wool panels, where the waste comes from sheep farms. With this type of reuse, the integration between the needs of the place in terms of infrastructures and housing shortages and the availability of the materials and the reachable performance is fundamental.
An integrated assessment to ensure the fulfilment of the needs must be performed in order to optimise the environmental and economic costs. When the elements have ended their life cycle, it will again be necessary to make, in a cyclical way, evaluations relative to minimum performance and to the potential performance, as well as to identify the opportunity of further reuse or to predict end-of-life scenarios with less virtuous variables in function of the deterioration level. The endogenous reuse is therefore to "0 metre," while the exogenous reuse is to "0 km." Both help to encourage local sustainable development.
In schematic form, the process of the described reuse is shown below.



8.3 _Project of construction systems with reused elements

The design of construction systems with reuse elements that come from selective demolitions of safety systems aims to identify the possible modes of reuse, while at the same time, to raise awareness among companies and the public administration to the potential that they present. As previously described, if needed materials are not obtainable from selective demolitions, they will be identified within the local supply chain, with the purpose to trigger virtuous processes of territory regeneration.
The definition of constructive systems allows the companies, in function of the quantitative and qualitative availability of the materials/components that come from the disassembly of safety systems, to reuse them according to different modalities.
The variability of boundary conditions and regulatory requirements for the building structures in function of use intended use, needs highly flexible systems that allow the simple integration of functional stages.
The flexibility and adaptability of the projected systems encourage the enterprise to reuse in different circumstances, which increases the life cycle of the materials and, consequently, decreases the environmental damage.
Also, the designed construction systems exclusively present reversible connections that facilitate both a temporary use and the maintenance of stable use. Even if they are composed of reusable materials, the connection elements (bolts, nails brackets, anchor escarpments, etc.) will be, in most cases, new products.
Excluding the tube-clamp system and the multidirectional system, the number of connectors present in a safety system is less than the number of connectors required for the assembly of a site service, because they present a different structural step, along with deterioration problems and a different structural sizing of the connections.
Depending on the deterioration of the available materials, the enterprise will have to perform reconditioning treatments. Sometimes the execution of such treatments could eliminate the economic convenience to reuse. Therefore the reversibility, adaptability and flexibility of the individual systems, in addition to responding to the variability of needs, represent an incentive for reuse to the enterprise. The investment made by the enterprise to perform the reconditioning operations or to adapt/improve the components. It is cushioned by the possibility of reuse of the architectural organism for both the short and long term, through the simple variation of the positioning of the elements in the building system or by the addition of further elements that do not entail substantial changes in the already defined constructive system.
The following describes the definition of possible constructive systems, virtuous from a technological point of view, thanks to their environmental comfort and sustainability and indicate the possible variables needed to respond to changing boundary conditions.
Given the multiplicity of variables, the analysed construction systems are not exhaustive, but provide guide lines that may also be used with change dictated by the specific case (pre-design of structural elements, choice of the type of connection, variation of used materials in function of the availability, etc.).

The technological, thermo-hygrometric and environmental assessments

For each identified constructive system, technological, thermo- hygrometric and environmental assessments were carried out.
The technological assessment takes into account the priority requirements in the temporary works, such as:

- reversibility, understood as the possibility to go back over the constructive process,
- flexibility, understood as the constructive and dimensional predisposition to variation,
- time of assembly/disassembly, understood as the elapsing time between the start and end of the assembly/disassembly,
- ease of assembly /disassembly, understood as the immediacy of the connection/separation of the parts of the system between them.

From a perspective of sustainability and cost optimisation, these requirements are considered essential even in the case of stable work. It is apparent that in the case of temporary works it deals with inherent and essential requirements. However, in stable work are requirements to increase the quality of the building structure.
From a constructive point of view, due to these requirements, the parts of the system can be connected together, even when they present a substantially different structure. This opportunity allows us to create variable construction systems as a function of the availability of the materials/components at the construction site and in function of their deterioration level. In many cases, in fact, the safety systems are made by different systems that present a variable deterioration in function to the type of material, but also by their exposure to atmospheric agents.
When connections with screws are present (i.e. in most cases in presence of wooden elements), it is necessary to take into account that at each life cycle, a progressive deterioration of the tightening support will follow. It is estimated that in the case of wooden elements, the maximum numbers of cycles of screwing for the connection system functionality is equal to 5. When the screw no longer ensures a tighter grip because of the deterioration, it will be necessary to change the screwing point or the wooden support.
The assessment of the thermal-hygrometric comfort is made by calculating the thermal transmittance of factory elements and identifying the surface and interstitial presence of condensation. In some cases, interstitial condensation is present. This case is ignored when it assumes a temporary destination of the system and favours a building structure made almost entirely by reused materials with reversible connections. Between the operating cycles of the structure, an intervention of routine maintenance on the elements aimed at restoring the initial performance can be performed.
If the structure is used for a period of time greater than

that conventionally estimated for temporary constructions, a vapour barrier will have to be inserted, which helps to limit condensation.

Generally the vapour barrier needs adherence to a rigid support. Therefore, it is placed down by gluing or using adhesive strips, a factor that negatively affects its reuse and sometimes the reuse of the support. The insertion of the vapour barrier is recommended, especially in the case in which the constructive element is isolated, with the aim to avoid the deterioration of the insulation because of the condensation. With the insertion of a vapour barrier, its impact must also be considered in the environmental assessment.

In the end, the environmental assessment is carried out using the LCA (Life Cycle Assessment) method, which enables us to analyse the environmental implications of a product, during each phase of the life cycle, "from the cradle to the grave", including the extraction and the processing of raw materials, the manufacturing stage, transport, distribution, usage, any possible global or partial usage, collection, storage, recovery and the final disposal of their waste.

The cultural approach that led to the assessment of the life cycle of a product, started between the 60's and '70s, as a result of the energy, oil and environmental crisis, which hit all industrialised countries and led to a growing concern for the exhaustion of fossil resources. The Midwest Research Institute set the stage of the actual methodology by investigating on behalf of Coca Cola Company the possibility for using alternative containers to glass bottles for beverages. The novelty of the method was not to assess a single productive process, as it had done until then, but to study the whole product.

During the 1980s, importance was given to the problem of solid waste and to soil deterioration, which consequently defined the concept of sustainable development, including the LCA method. Some scientific indicators that assessed the possibility of recycling or reusing a product and that assessed the pollutant emissions in the production of the some product were used. The guide lines of this method were published in some manuals (Manual of Energy Analysis by Boustead and Hancock). The 1990s inherited the studies from previous years and deepened them through the World Congresses of the SETAC (Society of Environmental Toxicology and Chemistry), which unified the procedures. This process of standardisation of the method was developed in 1997 with the enforced entry of a reference standard. Under the standards, the LCA procedure consists of four consecutive phases described below:

- Goal and scope definition (ISO 14040:2006 "Environmental management - Life cycle assessment - Principles and framework"), consists in defining the objectives, the field of application for the study, the reasons to conduct the study and the type of audience to which it refers. The elements that must be taken into account are: the functional unity and reference flow, the boundary of the product system, the quality requirements of the initial data, the type and scheme of the requested report. The functional unity represents a measure of the performance of the input stream and output. The boundaries of the system determines the units of process that must be included and are determined by numerous factors. The units of process interconnected by flows of intermediate products and/or by waste to be treated generate the system of products.
- Life Cycle Inventory (ISO 14041:1998 "Environmental management- Life Cycle assessment- Goal and scope definition and inventory analysis "), aims to inventory and consider the data of input from the environment (raw materials, energy source, ground, water, etc.), the systems of products (acquisition of raw materials, production, transformation, assembly, transport and distribution, usage and disposal), output to the economic system and environment (air, water and soil emissions, etc.). From a methodological point of view the units of process are defined in detail and, for each one indicated, the categories of associated data defines the input and output flows quantified by energy units of measurement. The data can be collected directly in the field (primary data) or derived from technical literature (secondary data). In the second case, it is important for those who draw up the LCA to have access to the model that is on the base of the construction of the data used, in order to evaluate the responsiveness with the matter in question.
- Life Cycle impact assessment (ISO 14042:2000 "Environmental management- Life cycle assessment- Life cycle impact assessment"), is the impact assessment that aims to point out the entity of environmental modifications that are generated as a result of release into the environment (emissions and wastewater) and with the consumption of resources, the objective is to numerically express the value of the environmental impact of the life cycle. The first step is that to select according to the chosen method, the impact categories of interest and indicators. The indicators can be on a global, regional and local scale. The inventory data should be included within the categories of impact. Each substance contributes in a different way to the same environmental problem; therefore, the input/output data of a particular substance are multiplied by an equivalent factor of characterisations, so as to obtain the potential impact, such as the effect of a substance on the environmental problem considered. The obtained values can be normalized or divided for a "reference value" or "normal effect" (average values or limits imposed by the legislation). In this way it establishes the relative importance of each environmental problem. In order to express the environmental impact in relation to a product, a single numeric value within the normalized data can be multiplied by the "weight factors" that express the criticality of each environmental effect. The added values provide the eco-indicator, that is a dimensionless numerical value that quantifies the impact of the system.
- Life Cycle Improvement (ISO 14043:2000 "environmental management - Life cycle assessment- Life cycle interpretation") consists in the interpretation and improvement with the aim to correlate the results of

the analysis of inventory and of the impact to point out the limits of the study and to propose recommendations. From an operational point of view are the following steps: verification of compliance between the objectives and the results, identification of main aspects highlighted by the results of previous phases, control through the variation of used parameters to watch the effects on the final results, conclusions pointing out the limits of the study and recommendations.

Despite the required steps being defined, it is up to the designer to discern the weight to be attributed to each assessment to obtain a reliable result on the sustainability of the intervention.

The assessment of the impact was carried out according to the complex indicators of IPCCP 2007[6] and the indicators from ReCiPe[7]. The IPCCP 2007 (Intergovernmental panel on Climate Change) method provides the results in terms of kilograms of CO2 equivalent (kgCO2eq) through the standardisation of the global warming potential (GWP Global Warming Potential), that measures how much gas contributes to the greenhouse effect, in a time reference of 100 years (horisontal time), calculated for each greenhouse gas taking into account the capacity to absorb radiation and the time of permanence in the atmosphere.

The GWP is calculated as:

GWP= (∫0TH ai [Ci (t)]dt / (∫0TH ar [Cr (t)]dt

where:

ai = radiative efficiency, represents the variation of the radiative forcing for each unit increase of the concentration of the agent "i" in atmosphere as a greenhouse gas;

Ci (t) = concentration of the agent, time function;

ar = radiative efficiency of the substance reference (CO2);

Cr (t) = concentration of the substance of reference;

TH = Time Horizont, temporal horizont, which is based on the analysis of GWP.

The quantity of CO2eq is calculated as:

CO2eq= Σi GWPi*Ei

where:

CO2 eq= emissions of CO2eq in kt/year;

GWPi = Global Warming Potential

Ei =emissions of CO2 (in kt/year),CH4 and N2O (in t/year).

Otherwise the method ReCiPe[8] provides the results in environmental impact points (Pt) and allows to assess, at an average level, 18 categories of impact:

- climatic change (CC),
- ozone depletion (OD),
- terrestrial acidification (TA),
- freshwater eutrophication (FE),
- marine eutrophication (ME),
- human toxicity (HT),
- photochemical oxidant formation (POF),

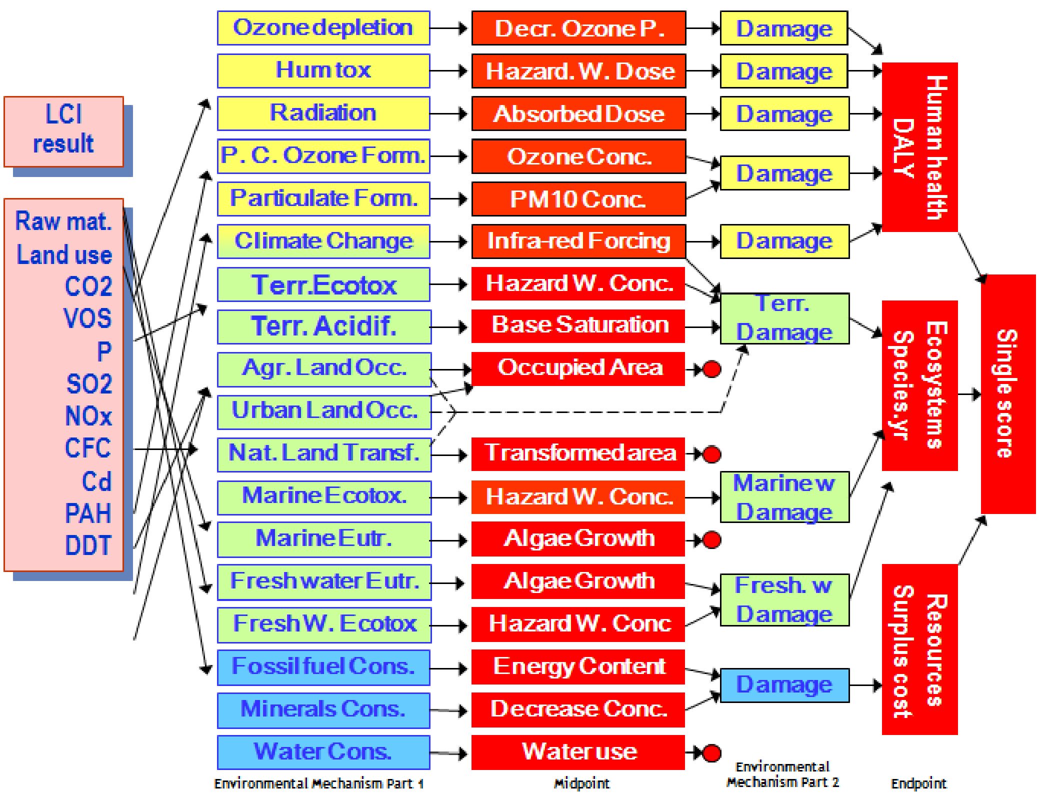


Fig. 1 _Method ReCiPe. Relation between indicators in mid-level, in final level and points of damage

- particulate matter formation (PMF),
- terrestrial ecotoxicity (TET),
- fresh water ecotoxicity (FET),
- marine ecotoxicity (MET),
- ionising radiation (IR),
- agricultural land occupation (ALO),
- urban land occupation (ULO)
- natural land transformation (NLT),
- water depletion (WD),
- minerals resource depletion (MRD),
- fossil fuel depletion (FD).

The final level considers three categories of damage:

- damage to human health (HH),
- damage to ecosystem diversity (ED),
- damage to resource availability (RA).

The three categories of damage are normalised by standardising the measurement unit and assessment by attributing different weights to them. Three macro steps are made in the study: the production that includes the steps of extraction of the raw material to the realisation of the product, the usage that includes the steps from the transportation site to the demolition and the end-of-life that includes the steps of transportation and reuse, recycling, recovery of the energy feedstock or transportation to the landfill.

For what concerns the macro steps of production for the reused materials, it considers an environmental impact equal to half of the value of production of a newly produced identical material. The obtained data are strongly conservative, because they contemplate the unfavourable hypothesis where the material is used only once. In consideration of the temporary nature of the constructive projected systems designed, it is evident that this value will be reduced in function depending on the number of actual reuses of factory elements that compose the construction equipment. It is assumed, in fact, that each time in which the element is reused, it avoids the new production of a similar product. For a more specific analysis, as well as the number of reuses (particularly important in the assessment of temporary structures), must also evaluate the number of years during which the element is used compared to the expected durability or from the condition of maximum performance to the condition of inadequate performance for the initial expected use.

The assessments are not exhaustive because the circumstances must take into account the element. After having undergone a reuse cycle, it does not ensure full, original performance. It is reused in way that requires the lower performance be taken into account. In this case, the reuse of the element compensates the environmental impact of the production of two products, the one with increased performance and the with minor performance. Further considerations can be made about the environmental impact of the maintenance treatments (during the life cycle, or reconditioning at the end-of-life cycle) of the elements and the increase of durability on the same.

For what concerns the macro phase of reuse, only the impact of transportation at a distance of 100 km is considered, such as in kilometric area where the Ithaca Protocol defines a local material and the impact of assembly and disassembly.

The environmental impact that results from the phase of use of the building structure and the phase of management that predominantly affects energy consumption are neglected, as such incidences present a high variability in function to the number of years of reuse and of the function to which the structure is intended.

For the end-of-life phase, the type of used materials (mainly steel and wood) allows us to hypothesise virtuous scenarios such as recycling, which in the calculation of the IPCC 2007 method and ReCiPe, amount to no impact. The approximation can be considered acceptable in view of low incidence on the global environmental impact compared to the other life cycle stages of the elements. It follows that the identified environmental impact values are mainly affected by the macro phase of production.

In light of the highly variability of the boundary conditions, the environmental assessment has been made compared to each specific case and it is impossible to generalise the results. Therefore, individual values do not provide reliable data about the numerical data of environmental pollution, but they do provide a point of comparison between the designed and assessed factory elements in the same conditions, which are aimed at identifying the convenience of reuse of specific systems under examination.

The projected constructive systems are presented to describe the components that constitute them, the phase of disassembly and analysis of the technological details. The geometric and dimensional characteristics of the components are relevant to the analysis conducted in the preliminary site on the safety systems placed in the building. In case of variations with these characteristics, the types of connectors must vary accordingly, notwithstanding the constructive logic of the system. The vertical closings are indicated with the initials CV, the horizontal lower closing with the initials COi and the horizontal upper closing with the initials COs. Compared to the basic definition of the constructive systems, some variations are proposed that describe the components and the construction details and the completed assessments. In some cases, the variation consists in adding a functional layer, in others, changing some of the building elements. The variations are indicated with letters (a, b and c).

For each part of the construction system, the results of variations are outlined. For the technological assessment, we consider the requirements on a scale from 1 to 10, for the assessment of thermal- hygrometric comfort we list the layers, its thermal properties and draw up a diagram of the pressure. For the environmental assessment, we provide overall results of the analysis according to the method IPCC2007, 100 year method and the ReCiPe method by dividing the phases of production, use and end-of-life. The detailed results, according to the IPCC 2007, 100 year method, with indication of the material quantity for each functional unit and relative impact, are provided in digital form (Appendix D). Comparing the assessments between the building systems and their variants and also between the same constructive systems, it is possible to identify the solution that best suits the requirements of the intended use for the construction organism and material availability.

Vertical closure n_1

CV_1

COMPONENTS

Wooden elements

120x25 mm

250x50 mm

200x50 mm

300x40 mm

Steel connections

Screw 10x400 mm

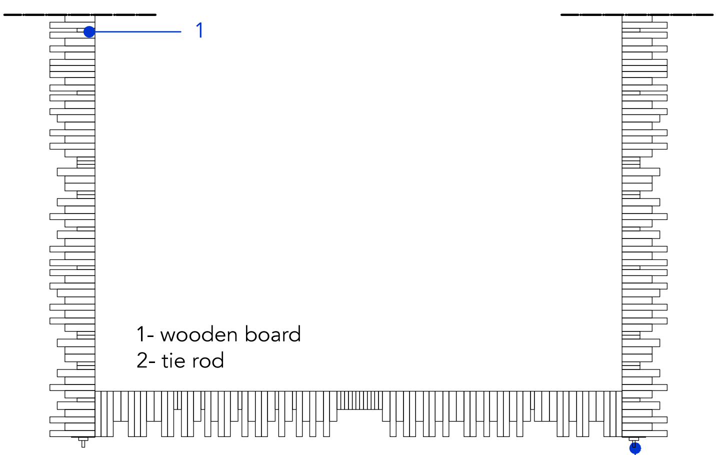
Nut and locknut M33

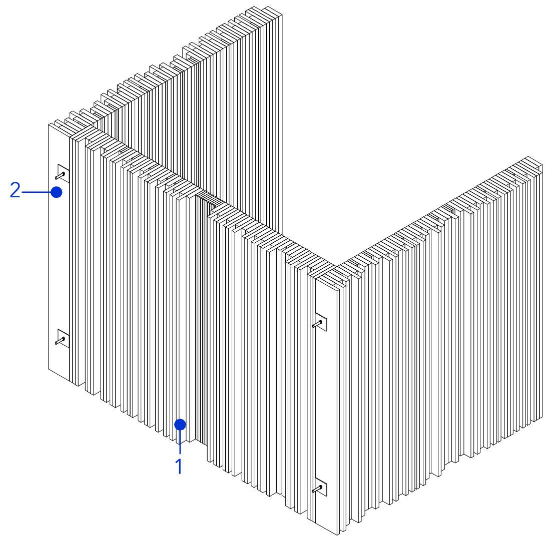
Tie-rod diam.18

Anchor plate

The length of the boards is uniform and must be at least 2700 mm

CONSTRUCTIVE DETAIL

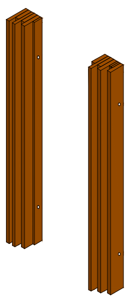




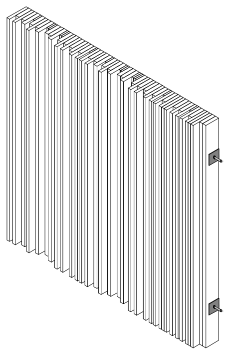
scale 1:50

ASSEMBLY STEPS

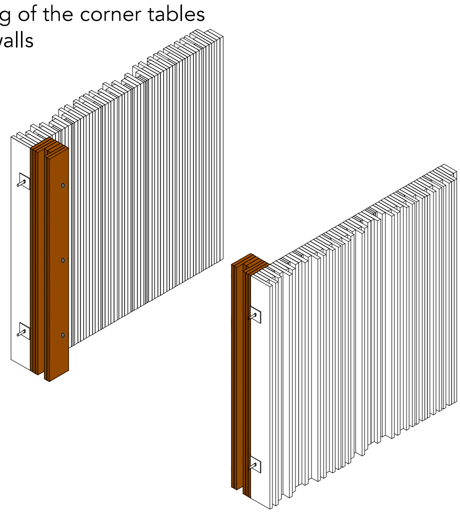
STEP_1
Positioning and
drilling of the boards



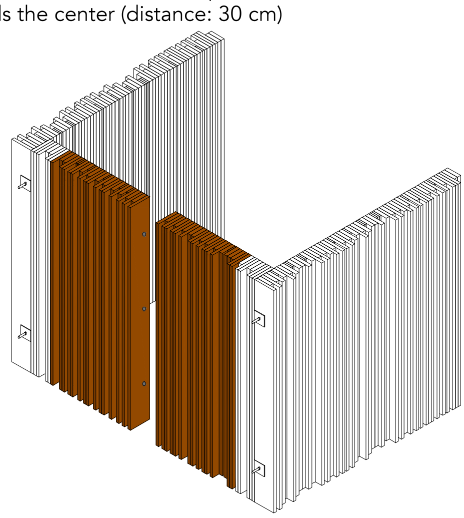
STEP_2
Insertion
and locking of the tie rods



STEP_3
Screwing of the corner tables
to the walls

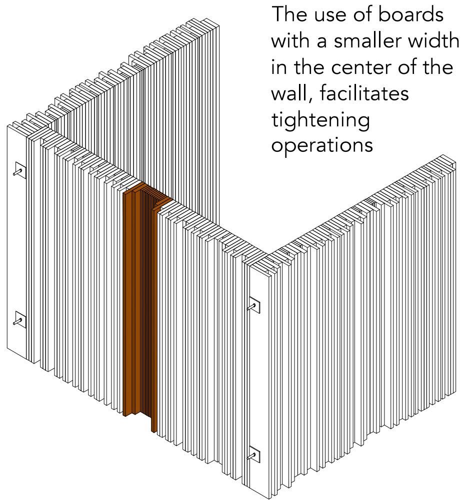


STEP_4
Screwing of the boards with progressing assembly
towards the center (distance: 30 cm)



STEP_5
Screwing of the boards centrally

The use of boards
with a smaller width
in the center of the
wall, facilitates
tightening
operations



variation a

CV_1a

COMPONENTS

Wooden elements

120x25 mm
250x50 mm
200x50 mm
300x40 mm
50x50 mm

Steel connections

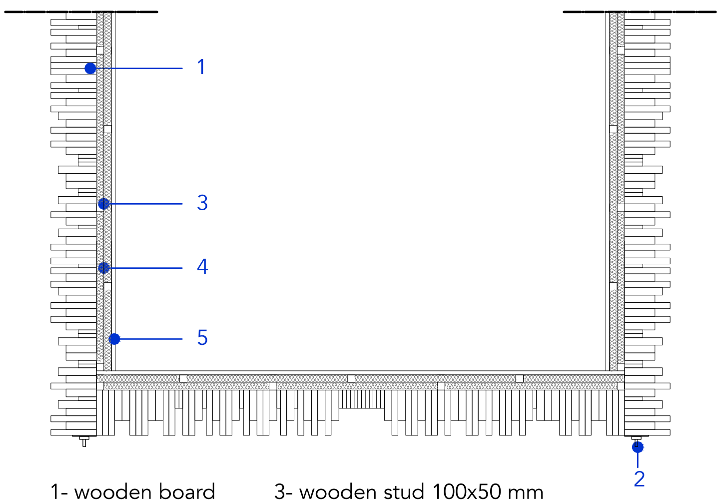
Screw 10x400 mm
Screw 8x90 mm
Screw 9x200 mm
Tie rod diam.18
Anchor plate
Nut and locknut M33

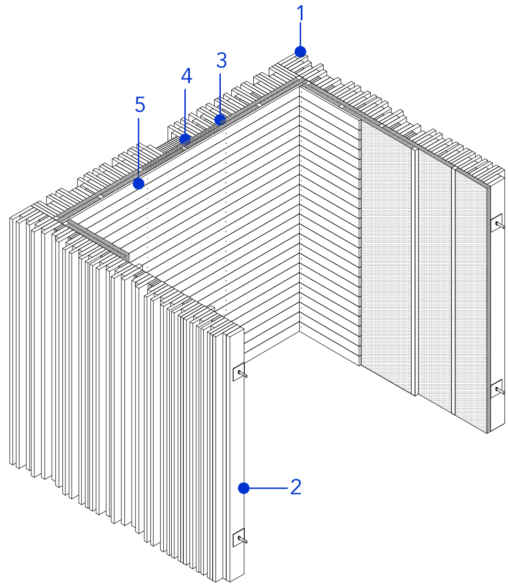
Insulation

Sheep wool 2000x2700x50mm

The length of the boards is uniform and must be at least 2700 mm

CONSTRUCTIVE DETAIL





1- wooden board
2- tie rod

3- wooden stud 100x50 mm
4- sheep wool insulation 50 mm
5- wooden board 120x25 mm

scale 1:50

variation b

CV_1b

COMPONENTS

Wooden elements

120x25 mm
250x50 mm
200x50 mm
300x40 mm

The length of the boards is not uniform

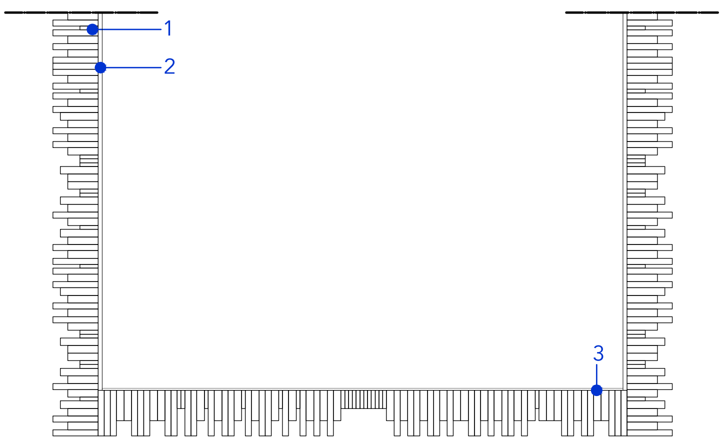
Steel connections

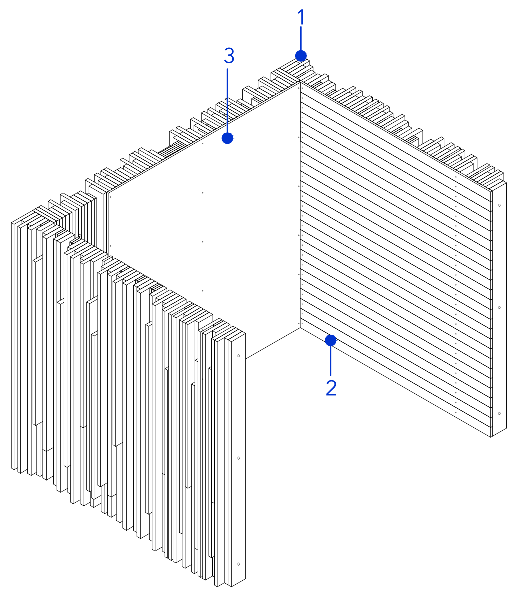
Screw 10x400 mm
Screw 6x200 mm
Silicone

Panels

Alveolar polycarbonate panels 2100x2700x10 mm

CONSTRUCTIVE DETAIL



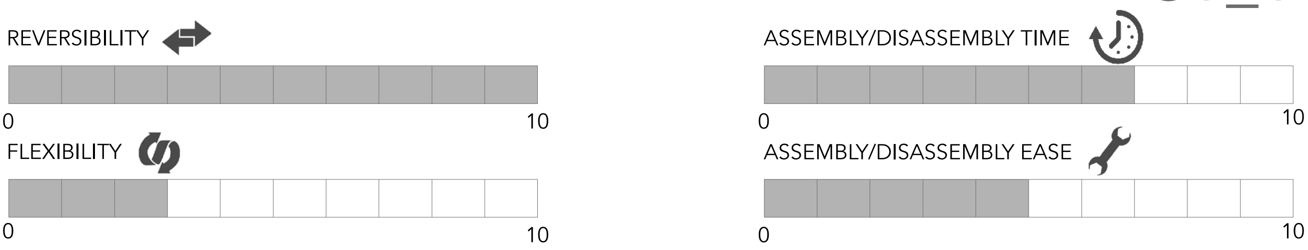


1- wooden board
2- wooden board 120x25 mm
3- alveolar polycarbonate panel

scale 1:50

Technology assessment

CV_1



Environmental comfort

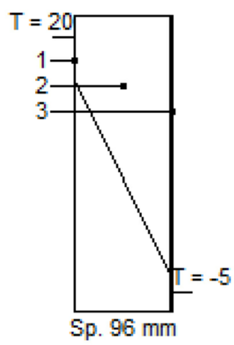
CV_1

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

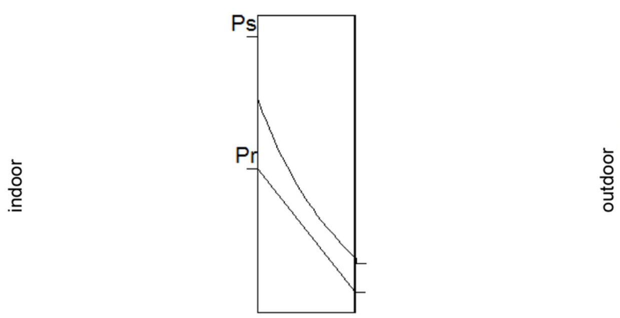
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Indoor adduttance	0		7.700			0	0.130
2	Pine boards	96	0.154	1.604	52.80	4.500	1660	0.623
3	Outdoor adduttance	0		25.000			0	0.040

RESISTANCE = 0.793 m²K/W		**TRASMITTANCE** = 1.261 W/m²K
THICKNESS = 96 mm	**AREIC HEAT CAPACITY** (int) = 32.804 kJ/m²K	**SURFACE MASS** = 53 kg/m²
PERIODIC TRAMITTANCE = 1.05 W/m²K	**MITIGATION FACTOR** = 0.83	**DISPLACEMENT** = 3.50 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

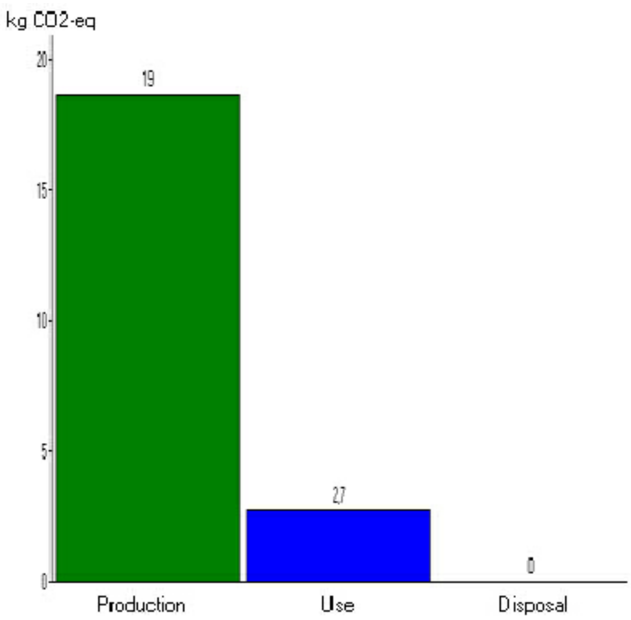


	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]	Te [°C]	Pse [Pa]	Pre [Pa]	URe [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

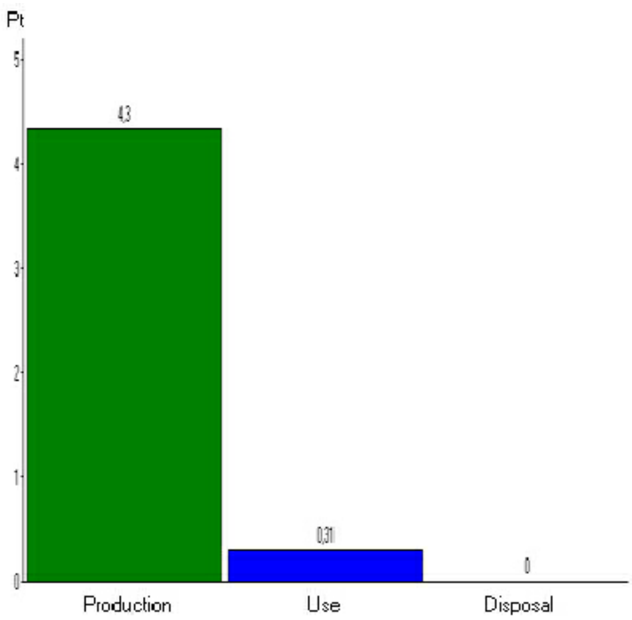
Life Cycle Assessment

CV_1

METHOD IPCC 2007- 21,7 KgCO2-eq

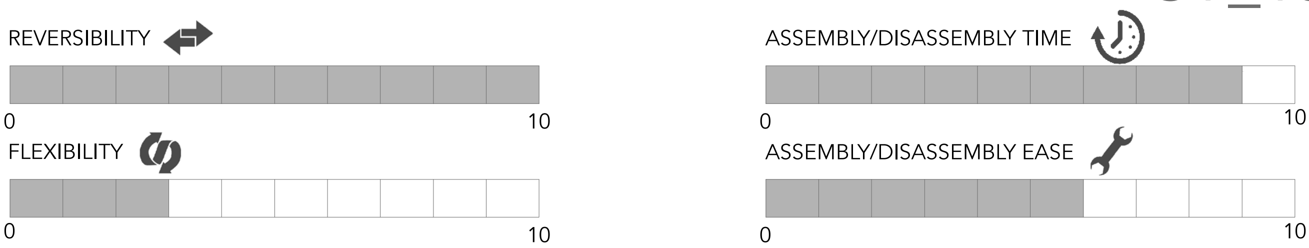


METHOD ReCiPe- 4,61 Pt



Technology assessment

CV_1a



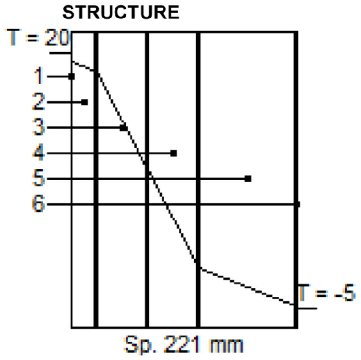
Environmental comfort

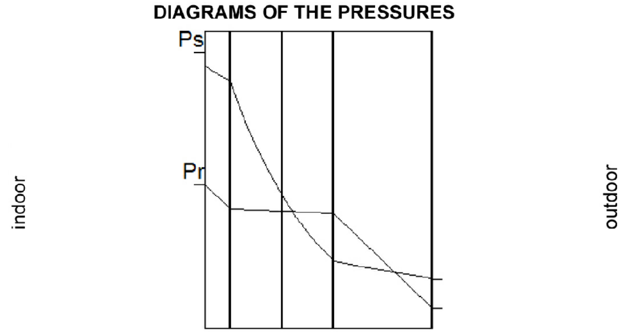
CV_1a

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Indoor adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Sheep wool insulation	50	0.032	0.636	1.50	96.500	1300	1.572
4	Sheep wool insulation	50	0.032	0.636	1.50	96.500	1300	1.572
5	Pine boards	96	0.154	1.604	52.80	4.500	1660	0.623
6	Outdoor adduttance	0		25.000			0	0.040

RESISTANCE = 4.100 m²K/W		**TRASMITTANCE** = 0.244 W/m²K
THICKNESS = 221 mm	**AREIC HEAT CAPACITY** (int) = 23.657 kJ/m²K	**SURFACE MASS** = 70 kg/m²
PERIODIC TRAMITTANCE = 0.12 W/m²K	**MITIGATION FACTOR** = 0.48	**DISPLACEMENT** = 7.39 h



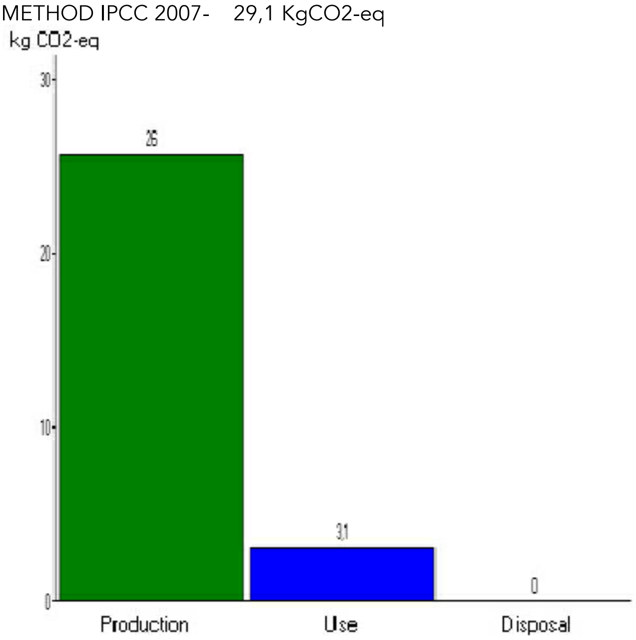


	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]	Te [°C]	Pse [Pa]	Pre [Pa]	URe [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

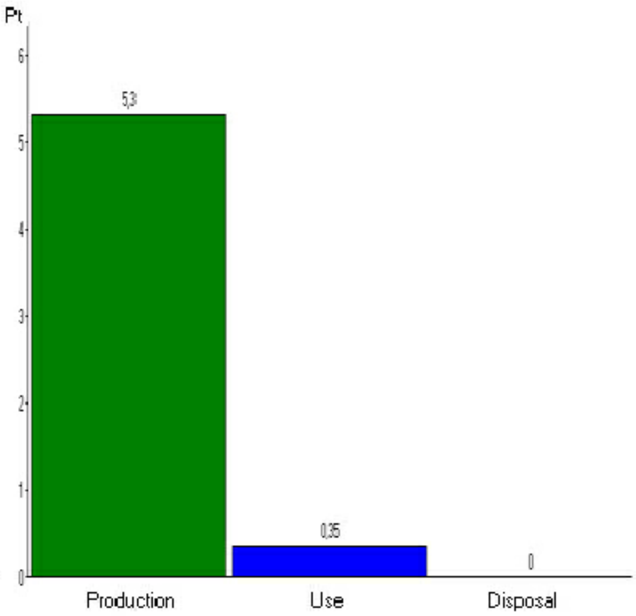
Life Cycle Assessment

CV_1a

METHOD IPCC 2007- 29,1 KgCO2-eq

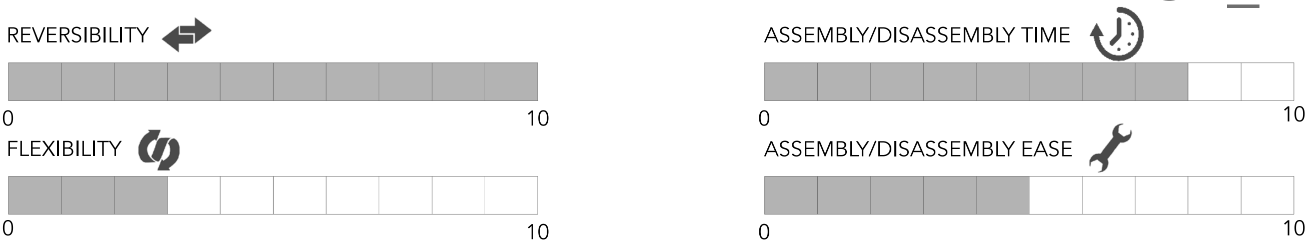


METHOD ReCiPe- 5,65 Pt



Technology assessment

CV_1b



Environmental comfort

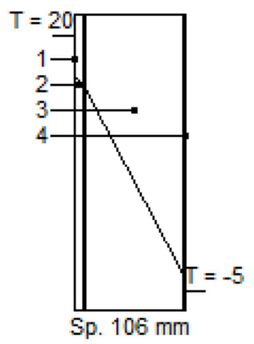
CV_1b

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

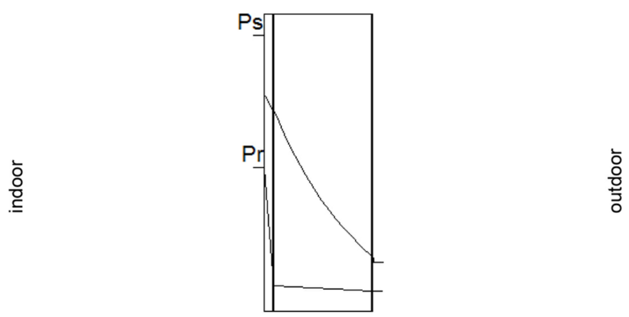
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Indoor adduttance	0		7.700			0	0.130
2	Polycarbonate panel	10	0.230	23.000	11.50	0.019	1	0.043
3	Pine boards	96	0.154	1.604	52.80	4.500	1660	0.623
4	Outdoor adduttance	0		25.000			0	0.040

RESISTANCE = 0.837 m²K/W		**TRASMITTANCE** = 1.195 W/m²K
THICKNESS = 106 mm	**AREIC HEAT CAPACITY** (int) = 30.293 kJ/m²K	**SURFACE MASS** = 64 kg/m²
PERIODIC TRAMITTANCE = 0.97 W/m²K	**MITIGATION FACTOR** = 0.81	**DISPLACEMENT** = 3.69 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

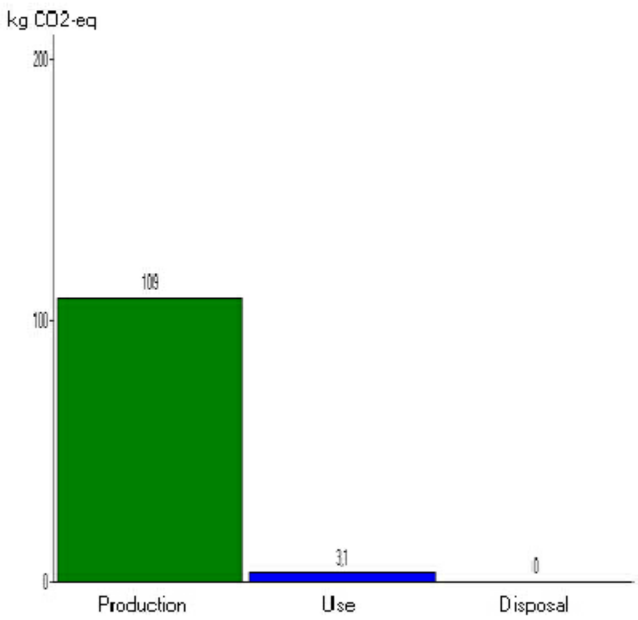


	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]	Te [°C]	Pse [Pa]	Pre [Pa]	URe [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

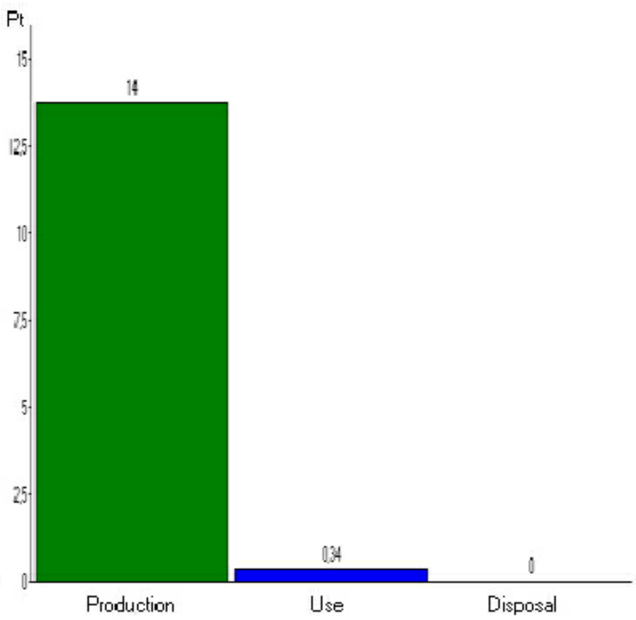
Life Cycle Assessment

CV_1b

METHOD IPCC 2007- 112,1 KgCO2-eq



METHOD ReCiPe- 14,34 Pt



Vertical closure n_2

CV_2

COMPONENTS

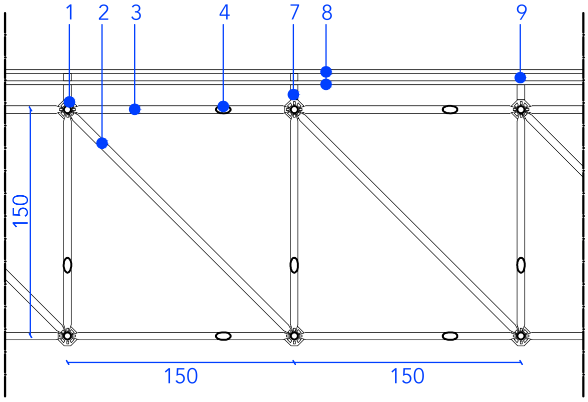
Wooden elements
- 50x50 mm
- 100x50 mm
- 120x25 mm

The length of the boards is uniform

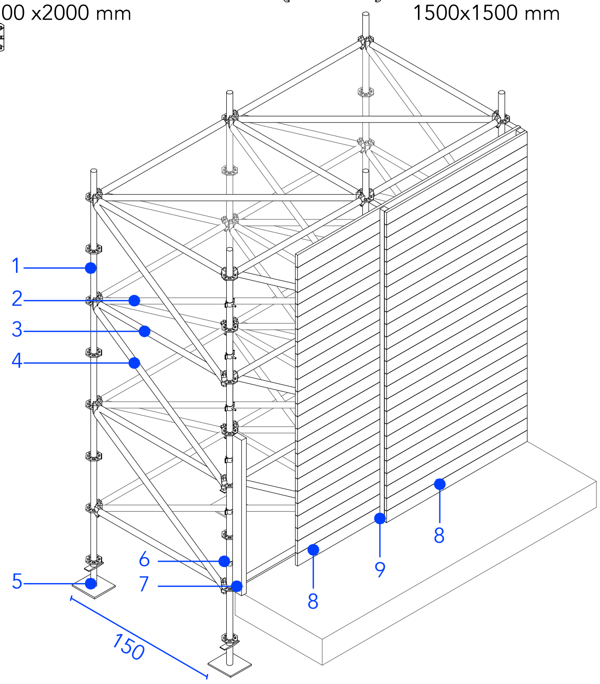
Steel connections
- Eyelet with screw
- Screw 5x40 mm

Multicom elements
- Vertical element 1500 mm without connection, 3000 mm with connection
- Vertical diagonal 1500 x2000 mm
- Base plate 500 mm
- Horizontal element 1500 mm
- Horizontal diagonal 1500x1500 mm

CONSTRUCTIVE DETAIL



1- vertical element
2- horizontal diagonal
3- horizontal element
4- vertical diagonal
5- base plate
6- eyelet
7- wooden stud 100x50 mm
8- board 120x25 mm
9- wooden stud 50x50 mm



scale 1:50

variation a

CV_2a

COMPONENTS

Wooden elements
- 50x50 mm
- 100x50 mm
- 120x25 mm

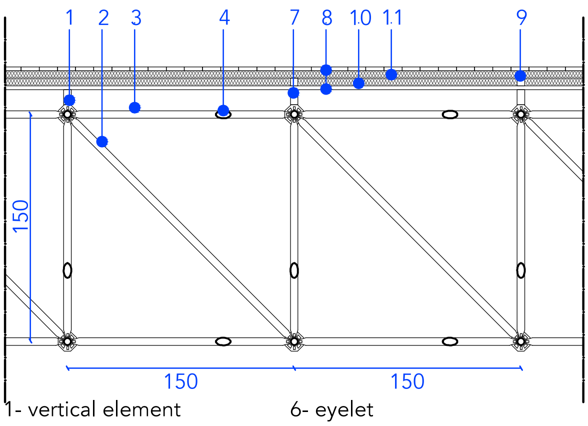
The length of the boards is uniform

Steel connections
- Eyelet with screw
- Screw 5x40 mm
- Screw 8x90 mm

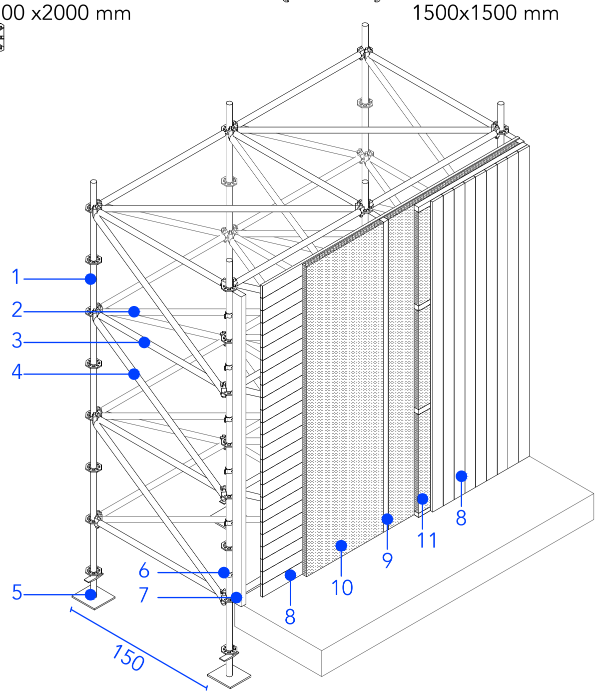
Multicom elements
- Vertical element 1500 mm without connection, 3000 mm with connection
- Vertical diagonal 1500 x2000 mm
- Base plate 500 mm
- Horizontal element 1500 mm
- Horizontal diagonal 1500x1500 mm

Insulation
- Sheep wool 1500x3000x50 mm
- Sheep wool 1000x l variable x50 mm

CONSTRUCTIVE DETAIL



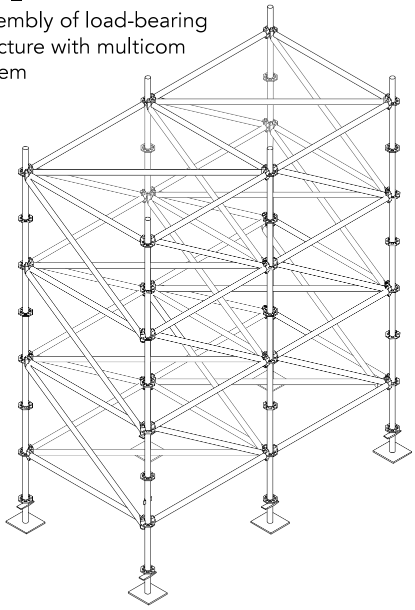
1- vertical element
2- horizontal diagonal
3- horizontal element
4- vertical diagonal
5- base plate
6- eyelet
7- wooden stud 100x50 mm
8- board 120x25 mm
9- wooden stud 50x50
10- wool insulation 1500x3000x50 mm
11- wool insulation 1000x l variable x50mm



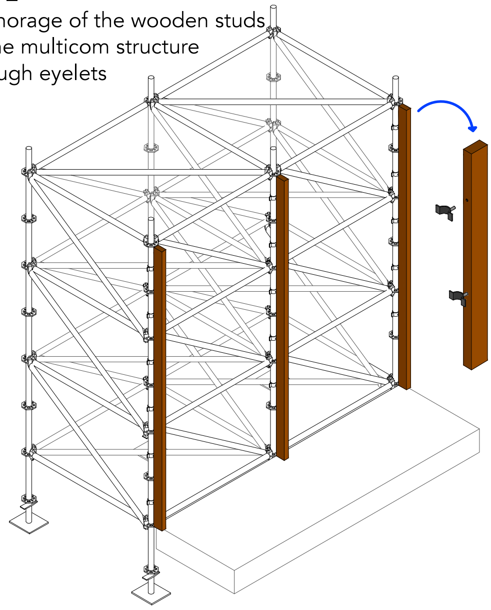
scale 1:50

ASSEMBLY STEPS

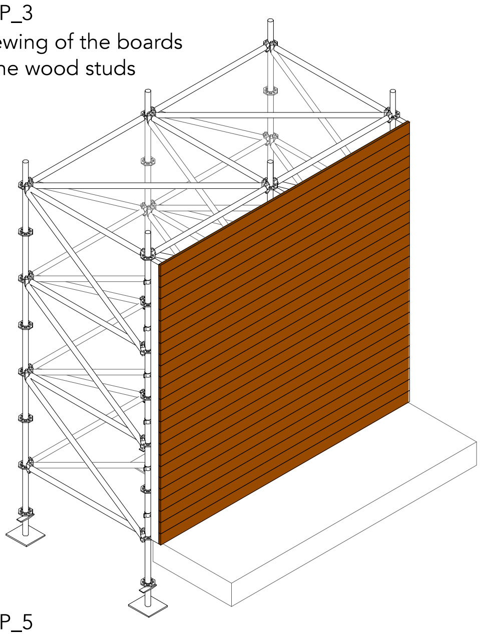
STEP_1
Assembly of load-bearing structure with multicom system



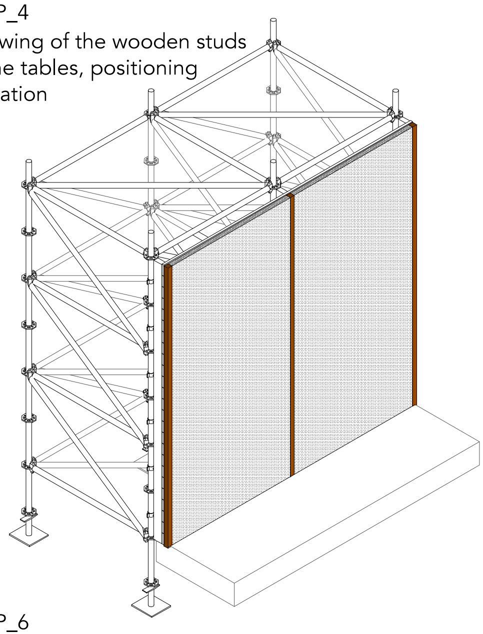
STEP_ 2
Anchorage of the wooden studs to the multicom structure through eyelets



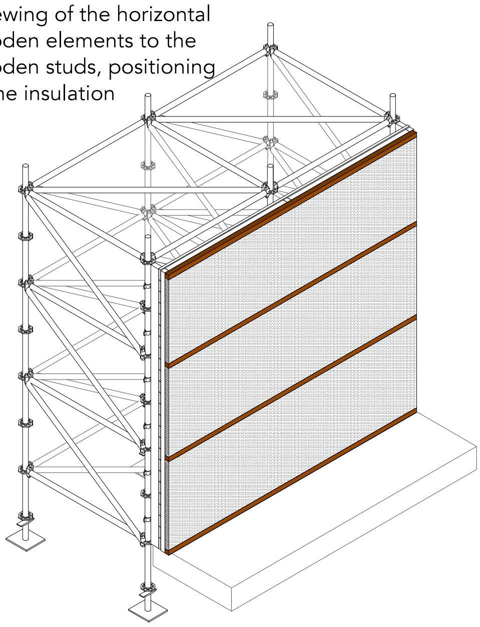
STEP_3
Screwing of the boards to the wood studs



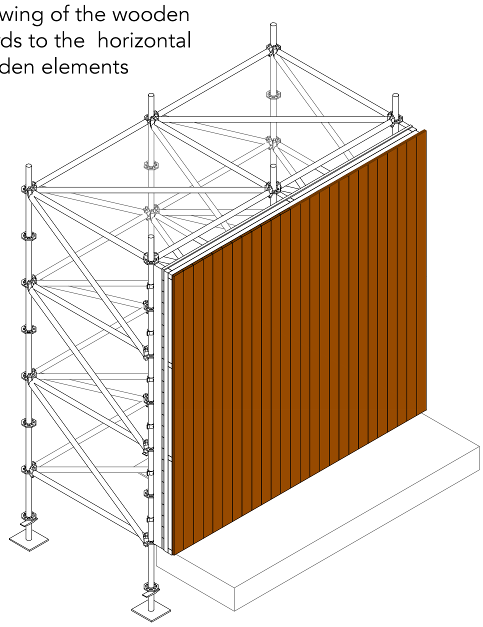
STEP_4
Screwing of the wooden studs to the tables, positioning insulation



STEP_5
Screwing of the horizontal wooden elements to the wooden studs, positioning of the insulation



STEP_6
Screwing of the wooden boards to the horizontal wooden elements

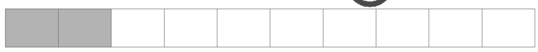


Technology assessment

CV_2

REVERSIBILITY

ASSEMBLY/DISASSEMBLY TIME



FLEXIBILITY

ASSEMBLY/DISASSEMBLY EASE

Environmental comfort

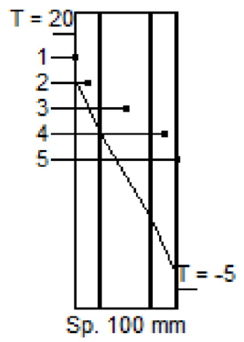
CV_2

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

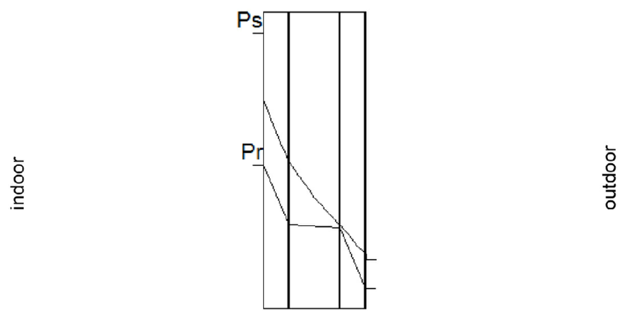
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Indoor addittance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Vertical air layer	50	0.200	4.000	0.05	193.000	1008	0.250
4	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
5	Outdoor addittance	0		25.000			0	0.040

RESISTANCE = 0.745 m²K/W		**TRASMITTANCE** = 1.343 W/m²K
THICKNESS = 100 mm	**AREIC HEAT CAPACITY** (int) = 19.226 kJ/m²K	**SURFACE MASS** = 28 kg/m²
PERIODIC TRAMITTANCE = 1.44 W/m²K	**MITIGATION FACTOR** = 0.97	**DISPLACEMENT** = 1.49 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

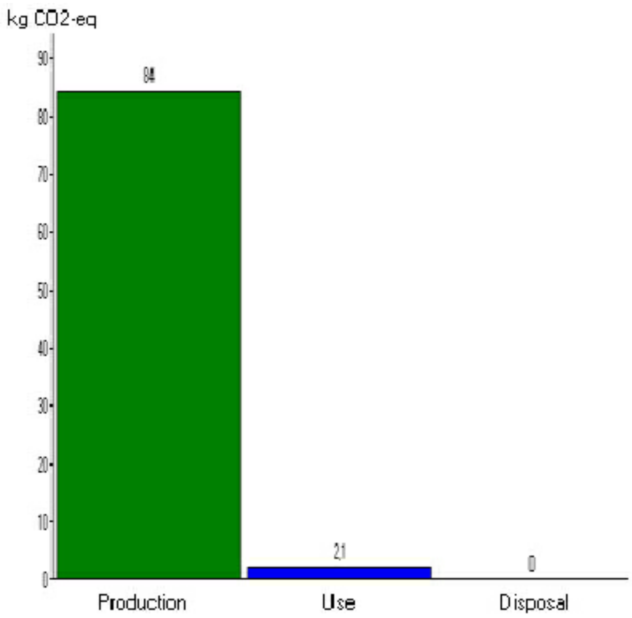


	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]	Te [°C]	Pse [Pa]	Pre [Pa]	URe [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

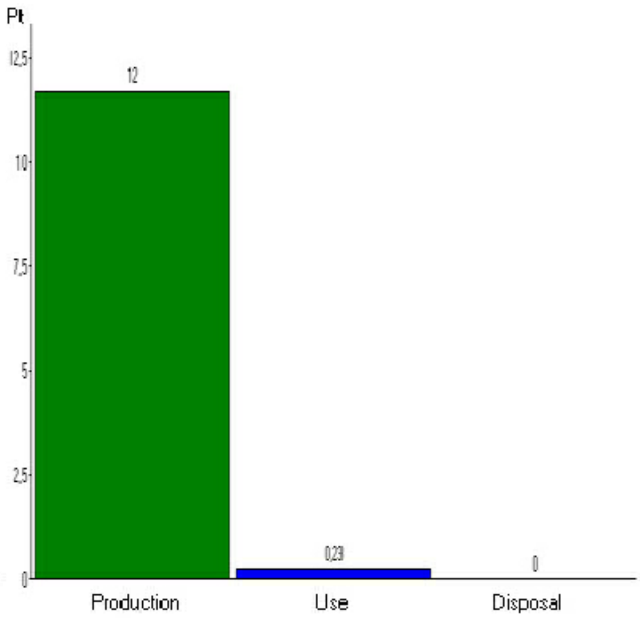
Life Cycle Assessment

CV_2

METHOD IPCC 2007- 86,1 KgCO2-eq



METHOD ReCiPe- 12,23 Pt



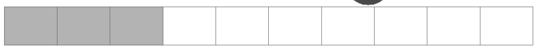
Technology assessment

CV_2a

REVERSIBILITY

0 10

ASSEMBLY/DISASSEMBLY TIME



0 10

FLEXIBILITY

0 10

ASSEMBLY/DISASSEMBLY EASE

0 10

Environmental comfort

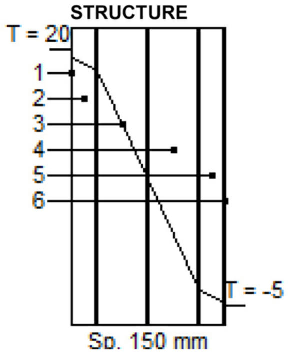
CV_2a

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

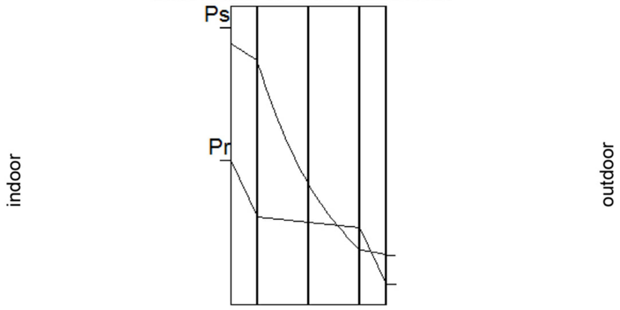
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Indoor adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Sheep wool insulation	50	0.032	0.636	1.50	96.500	1300	1.572
4	Sheep wool insulation	50	0.032	0.636	1.50	96.500	1300	1.572
5	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
6	Outdoor adduttance	0		25.000			0	0.040

RESISTANCE = 3.639 m²K/W		**TRASMITTANCE** = 0.275 W/m²K
THICKNESS = 150 mm	**AREIC HEAT CAPACITY** (int) = 22.941 kJ/m²K	**SURFACE MASS** = 31 kg/m²
PERIODIC TRAMITTANCE = 0.26 W/m²K	**MITIGATION FACTOR** = 0.93	**DISPLACEMENT** = 2.69 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

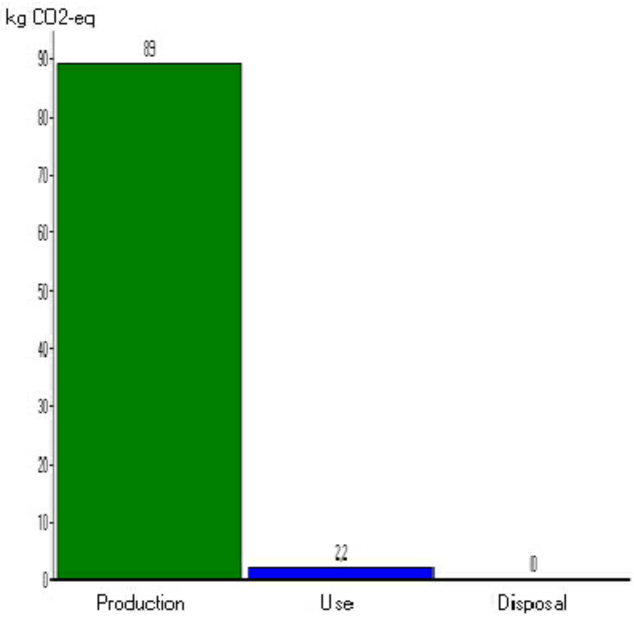


	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]	Te [°C]	Pse [Pa]	Pre [Pa]	URe [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

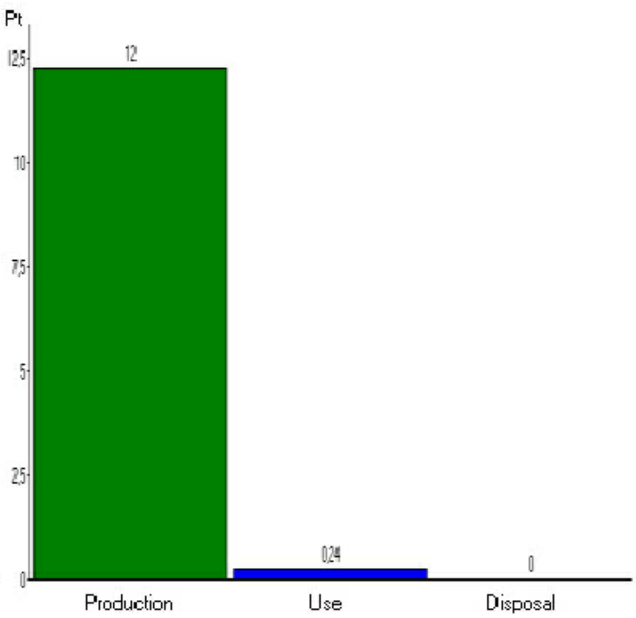
Life Cycle Assessment

CV_2a

METHOD IPCC 2007- 91,2 KgCO2-eq



METHOD ReCiPe- 12,24 Pt



Vertical closure n_3

CV_3

COMPONENTS

Wooden elements

- 50x50 mm
- 100x50 mm
- 120x25 mm

The length of the boards is uniform

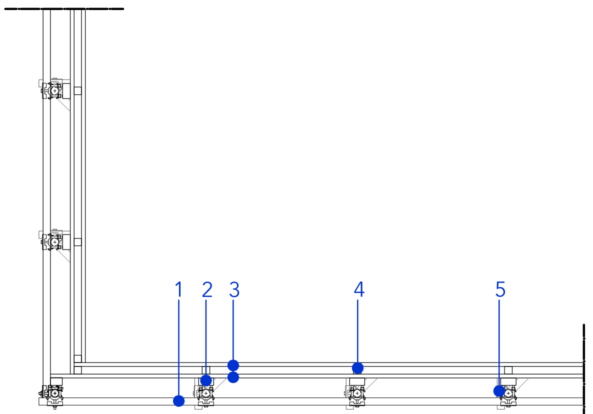
Steel connections

- Eyelet with screw
- Screw 5x40 mm
- Screw 8x90 mm

Tubular-joint system

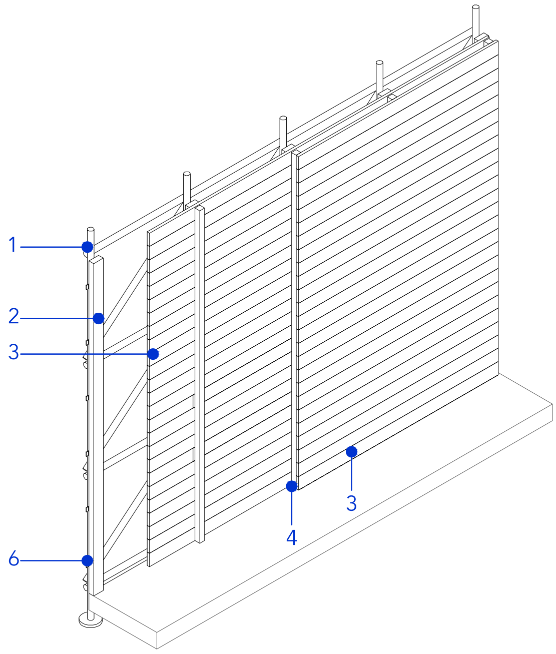
- Tubular element, l variable
- Base plate
- Right angle clamp
- Swivel clamp

CONSTRUCTIVE DETAIL



1- tubular element
2- wooden stud 100x50 mm
3- board 120x25 mm
4- wooden stud 50x50 mm
5- right angle clamp
6- eyelet with screw

scale 1:50



variation a

CV_3a

COMPONENTS

Wooden elements

- 50x50 mm
- 100x50 mm
- 120x25 mm

The length of the boards is uniform

Steel connections

- Eyelet with screw
- Screw 5x40 mm
- Screw 8x120 mm

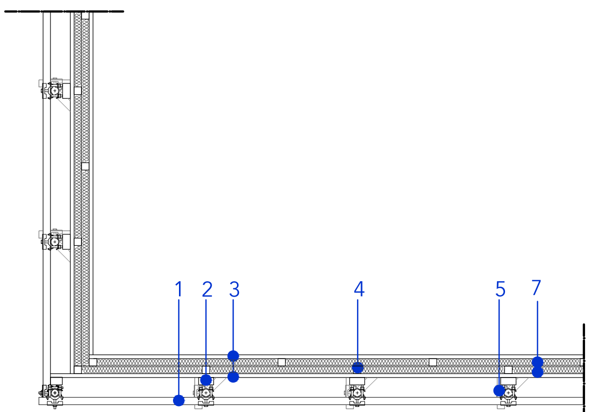
Tubular-joint system

- Tubular element, l variable
- Base plate
- Right angle clamp
- Swivel clamp

Insulation

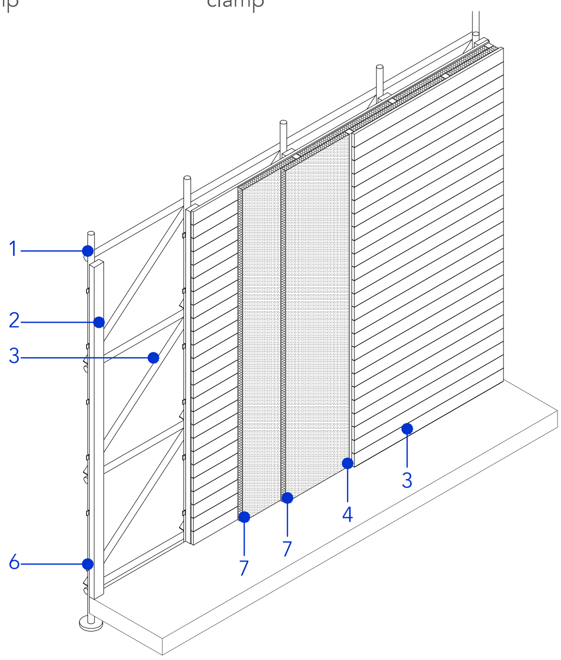
- Sheep wool 950x l variable x50 mm

CONSTRUCTIVE DETAIL



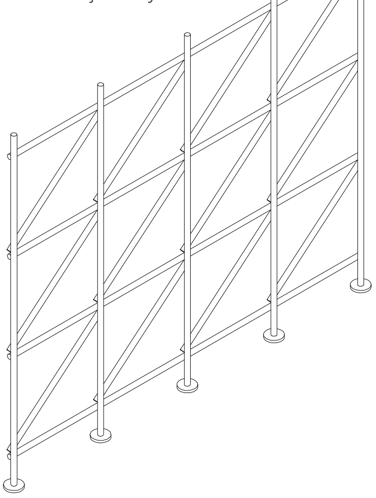
1- tubular element
2- wooden stud 100x50 mm
3- board 120x25 mm
4- wooden stud 50x50 mm
5- right angle clamp
6- eyelet with screw
7- wool insulation 950 x l variable x 50 mm

scale 1:50

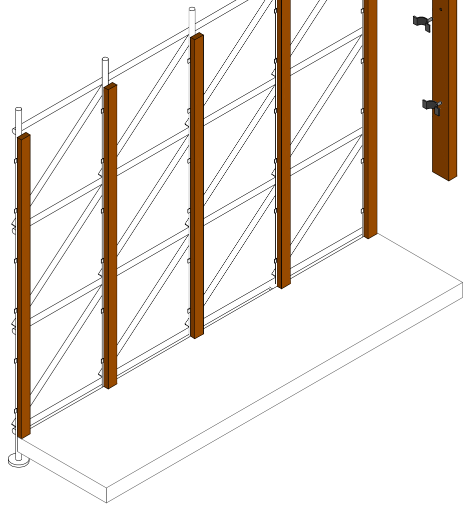


ASSEMBLY STEPS

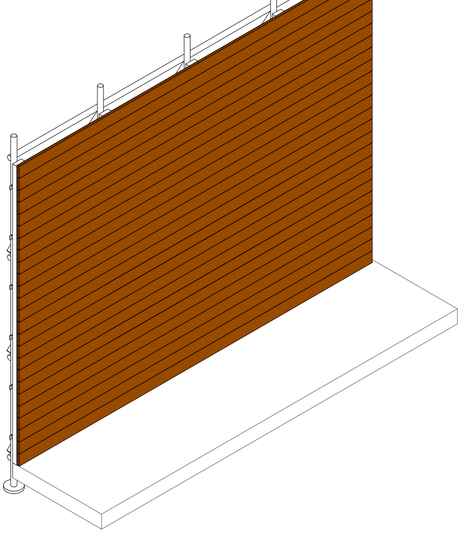
STEP_1
Assembly of load-bearing structure with tubular-joint system



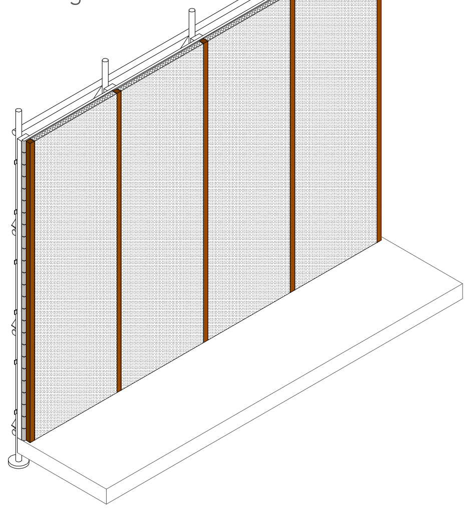
STEP_2
Anchorage of the wooden studs to the tubular structure through eyelets



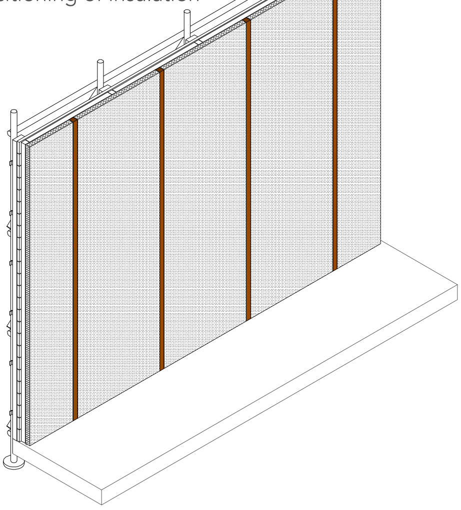
STEP_3
Screwing of the boards to the wood studs



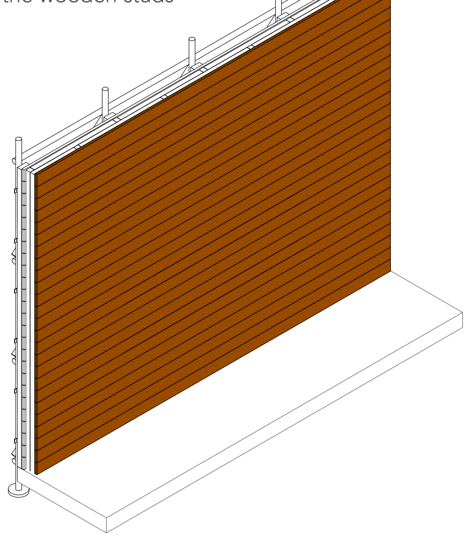
STEP_4
Screwing of the wooden studs to the tables, positioning of insulation



STEP_5
Positioning and screwing of the wooden studs, positioning of insulation



STEP_6
Screwing of the boards to the wooden studs

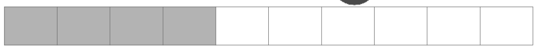


Technology assessment

CV_3

REVERSIBILITY

ASSEMBLY/DISASSEMBLY TIME



FLEXIBILITY

ASSEMBLY/DISASSEMBLY EASE

Environmental comfort

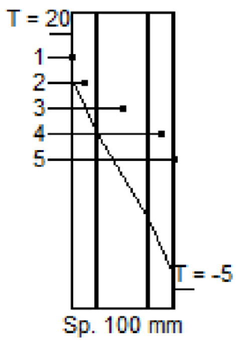
CV_3

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

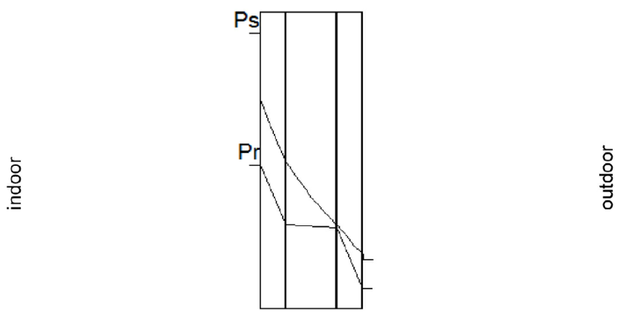
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Indoor adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Vertical air layer	50	0.200	4.000	0.05	193.000	1008	0.250
4	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
5	Outdoor adduttance	0		25.000			0	0.040

RESISTANCE = 0.745 m²K/W		**TRASMITTANCE** = 1.343 W/m²K
THICKNESS = 100 mm	**AREIC HEAT CAPACITY** (int) = 19.226 kJ/m²K	**SURFACE MASS** = 28 kg/m²
PERIODIC TRAMITTANCE = 1.44 W/m²K	**MITIGATION FACTOR** = 0.97	**DISPLACEMENT** = 1.49 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

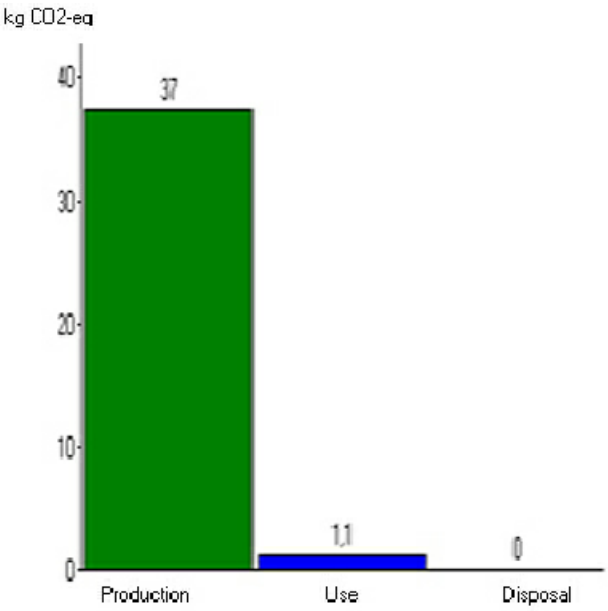


	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]	Te [°C]	Pse [Pa]	Pre [Pa]	URe [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

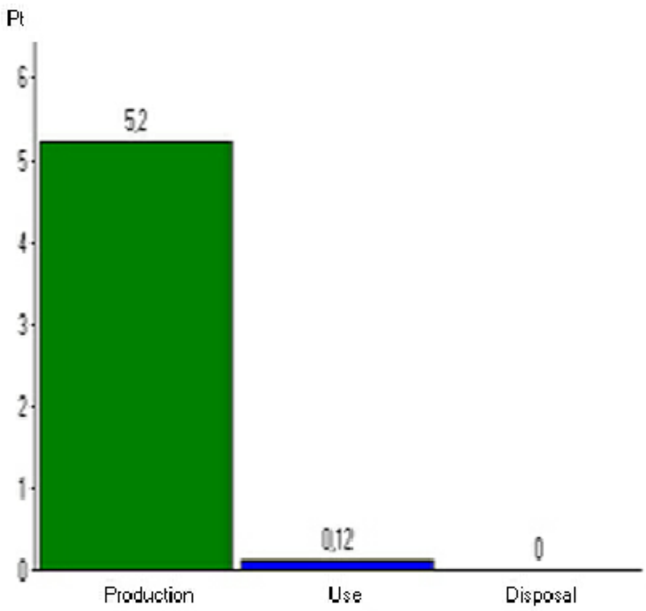
Life Cycle Assessment

CV_3

METHOD IPCC 2007- 38,10 KgCO2-eq

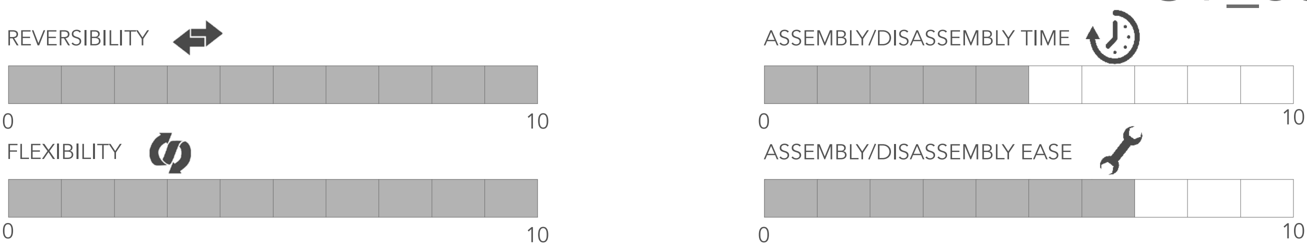


METHOD ReCiPe- 5,32 Pt



Technology assessment

CV_3a



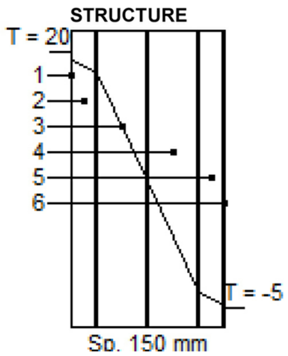
Environmental comfort

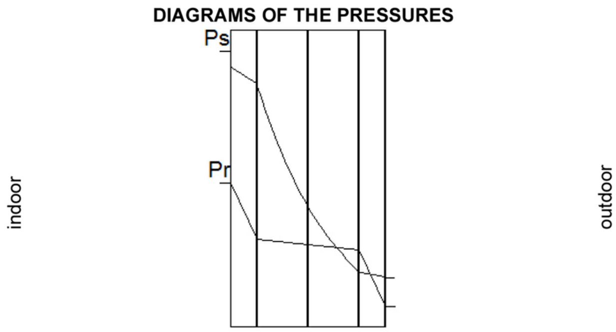
CV_3a

Municipality of L'Aquila, Climatic Area: E, Day degrees: 2514

N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Indoor addultance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Sheep wool insulation	50	0.032	0.636	1.50	96.500	1300	1.572
4	Sheep wool insulation	50	0.032	0.636	1.50	96.500	1300	1.572
5	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
6	Outdoor addultance	0		25.000			0	0.040

RESISTANCE = 3.639 m²K/W		**TRASMITTANCE** = 0.275 W/m²K
THICKNESS = 150 mm	**AREIC HEAT CAPACITY** (int) = 22.941 kJ/m²K	**SURFACE MASS** = 31 kg/m²
PERIODIC TRAMITTANCE = 0.26 W/m²K	**MITIGATION FACTOR** = 0.93	**DISPLACEMENT** = 2.69 h



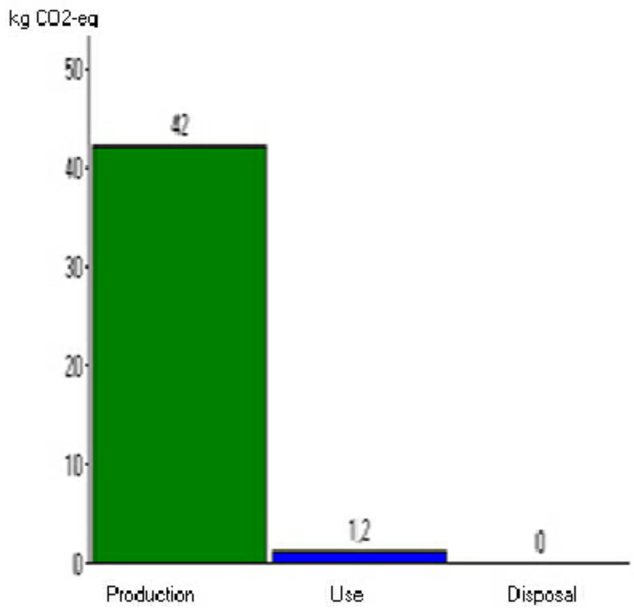


	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]	Te [°C]	Pse [Pa]	Pre [Pa]	URe [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

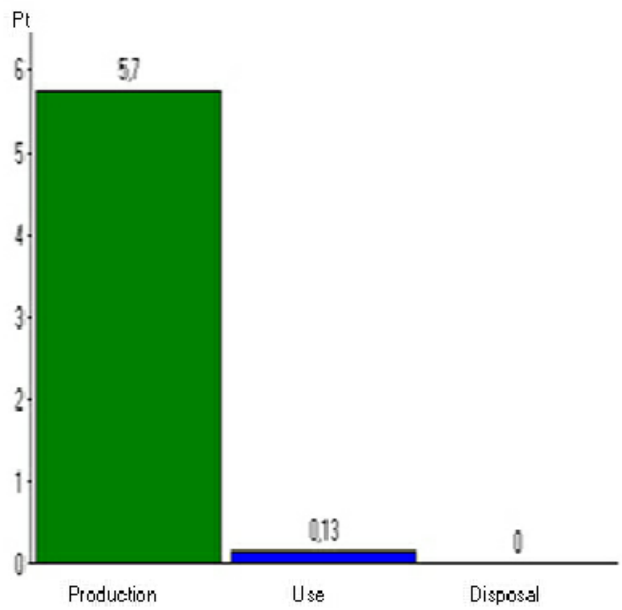
Life Cycle Assessment

CV_3a

METHOD IPCC 2007- 43,2 KgCO2-eq



METHOD ReCiPe- 5,83 Pt



Vertical closure n_4

CV_4

COMPONENTS

Wooden elements

- 120x25 mm
- 150x40 mm

The length of the boards is uniform

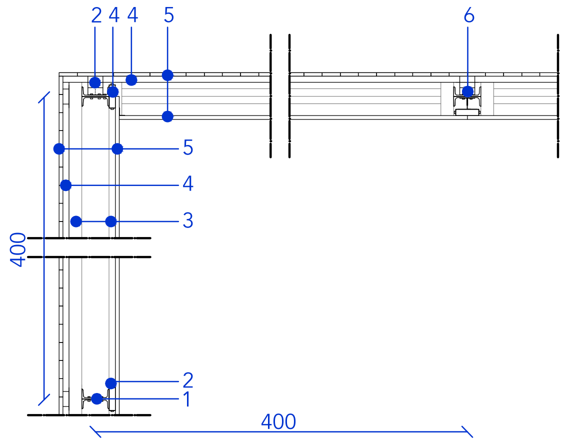
Steel profiles

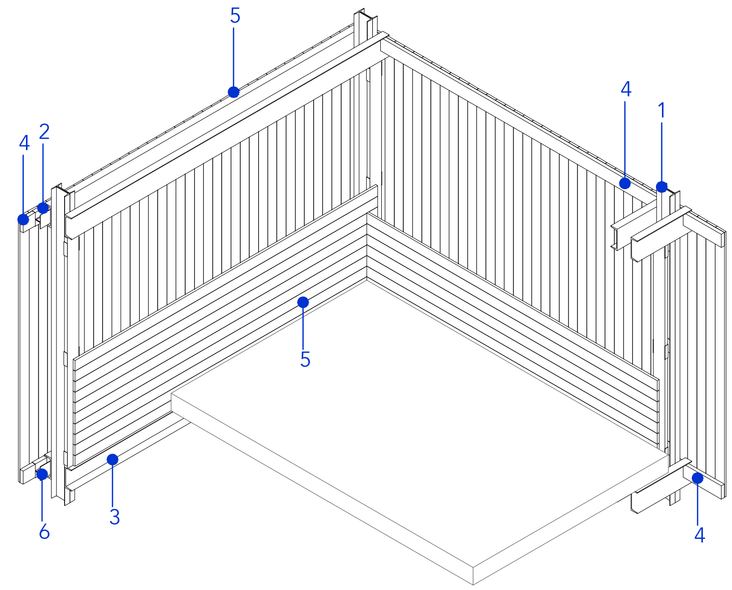
- UPN 240
- UPN 180

Steel connections

- Bracket 150x100 mm
- Bracket 100x100 mm connector 50 mm
- Screw 5x40 mm
- Bolt, nut and locknut

CONSTRUCTIVE DETAIL





1- UPN 180
2- bracket 150x100 mm
3- UPN 240
4- board 150x40 mm
5- board 120x25 mm
6- bracket 100x100 mm

scale 1:50

variation a

CV_4a

COMPONENTS

Wooden elements

- 120x25 mm
- 150x40 mm

The length of the boards is uniform

Insulantion

- Sheep wool 2000x3000x100 mm

Steel profiles

- UPN 240
- UPN 180

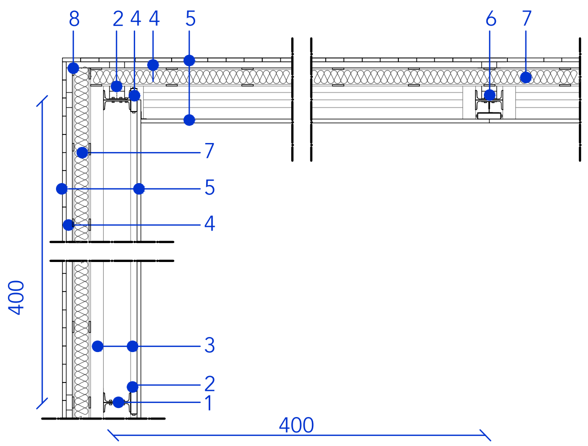
Band

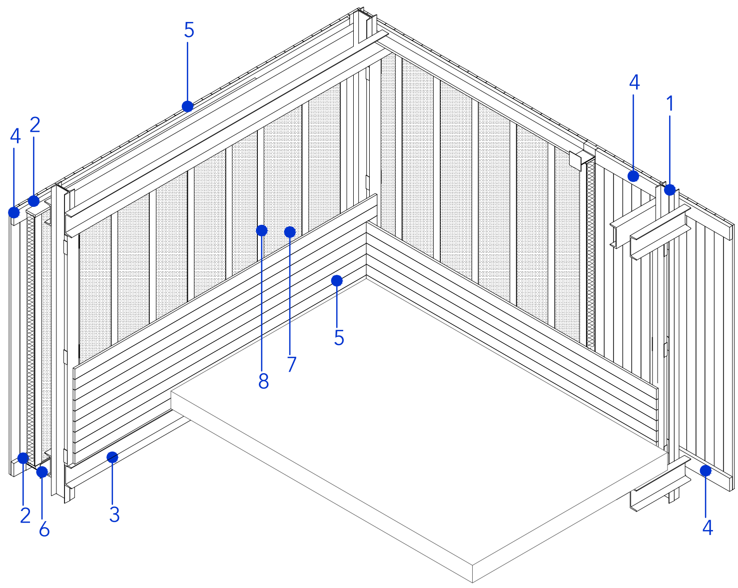
- Polyester h 75 mm

Steel connections

- Bracket 150x100 mm
- Bracket 100x100 mm connector 150 mm
- Screw 5x40 mm
- Bolt, nut and locknut
- Nail 20 mm

CONSTRUCTIVE DETAIL



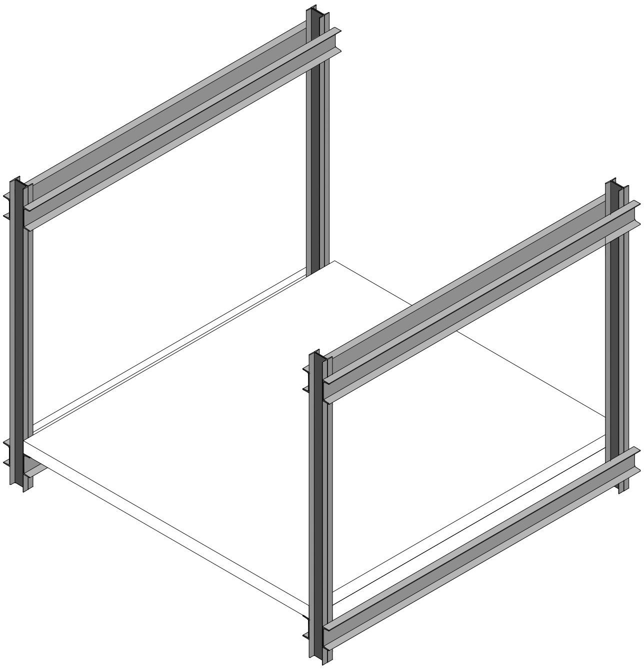


1- UPN 180
2- bracket 150x100 mm
3- UPN 240
4- board 150x40 mm
5- board 120x25 mm
6- bracket 100x100 mm
7- wool insulation 100 mm
8- polyester band h 50 mm

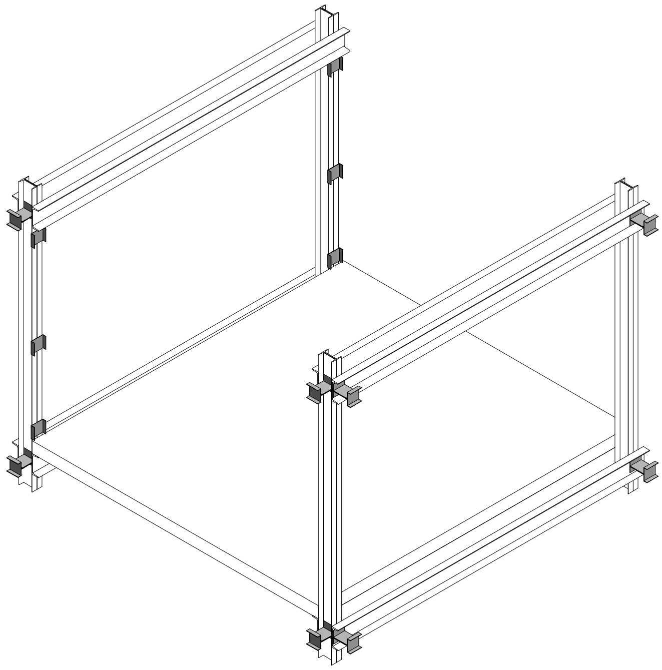
scale 1:50

ASSEMBLY STEPS

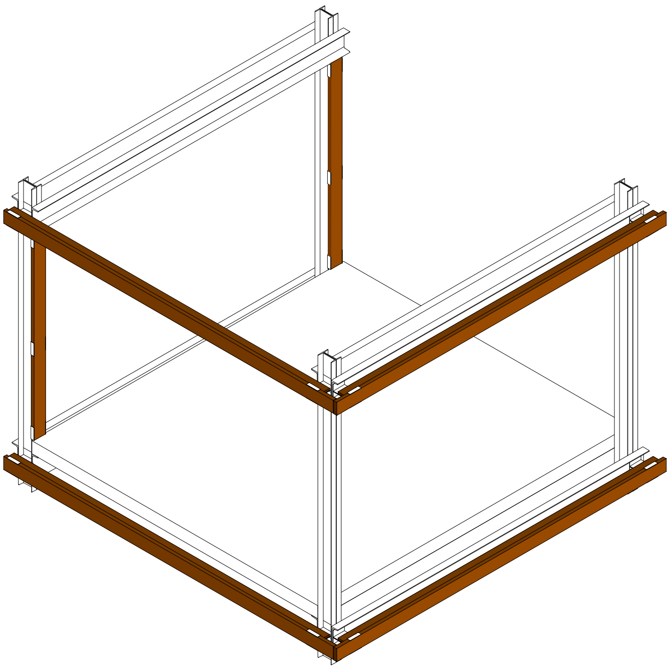
STEP_1
Assembly of load-bearing structure



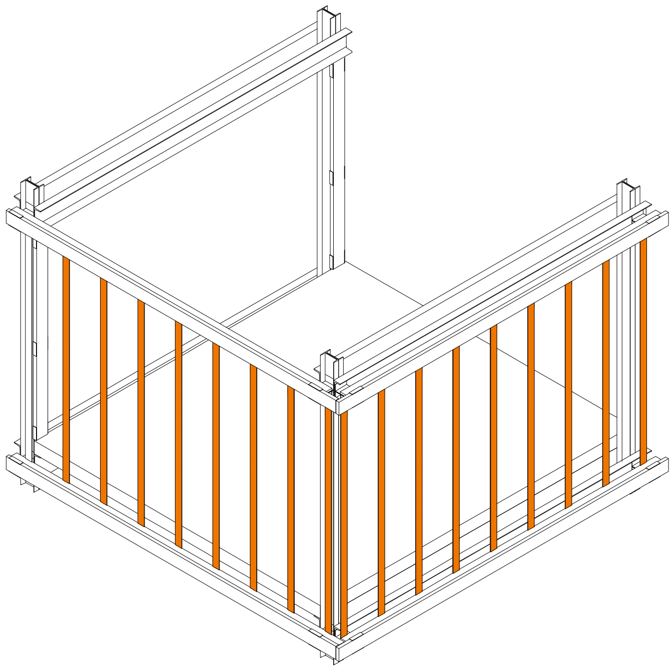
STEP_2
Assembly of the connections and brackets



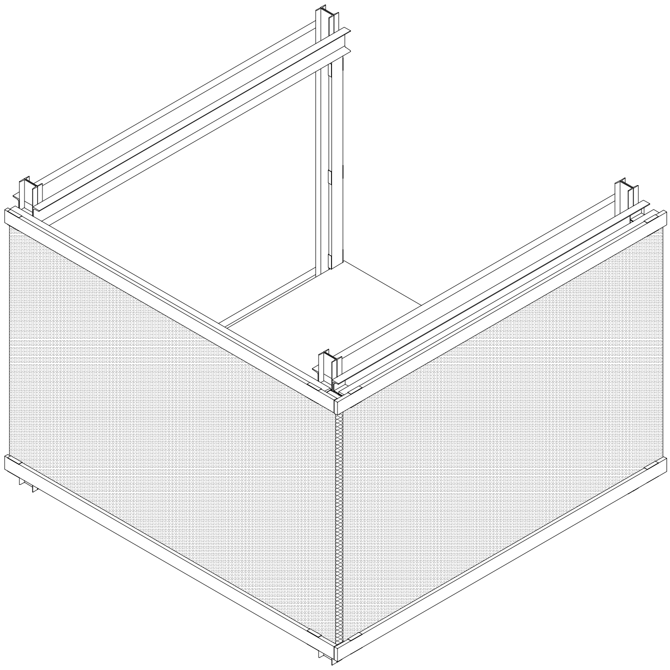
STEP_3
Screwing the boards 150 x 40 mm to the brackets



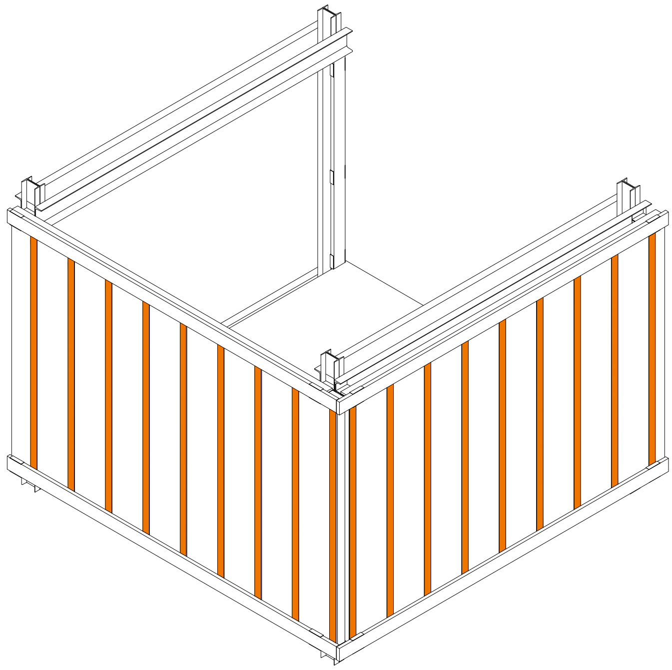
STEP_4
Nailing the polyester bands to the wooden boards



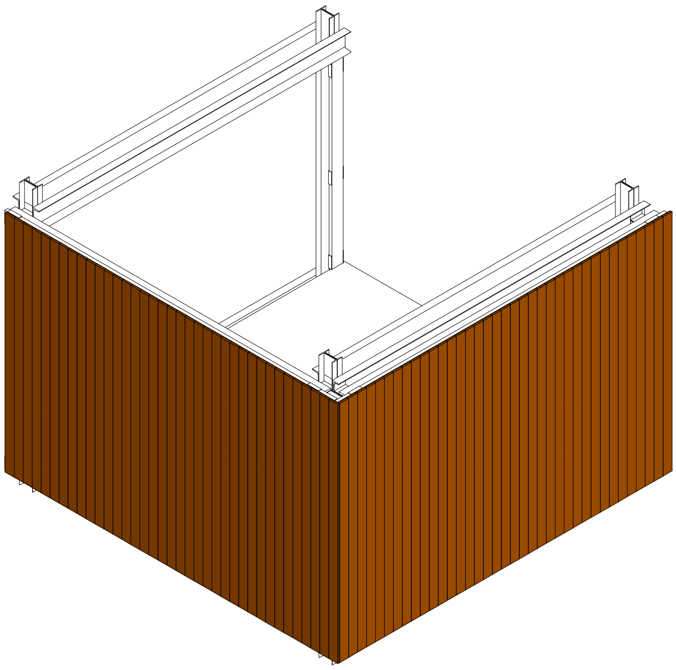
STEP_5
Positioning insulation



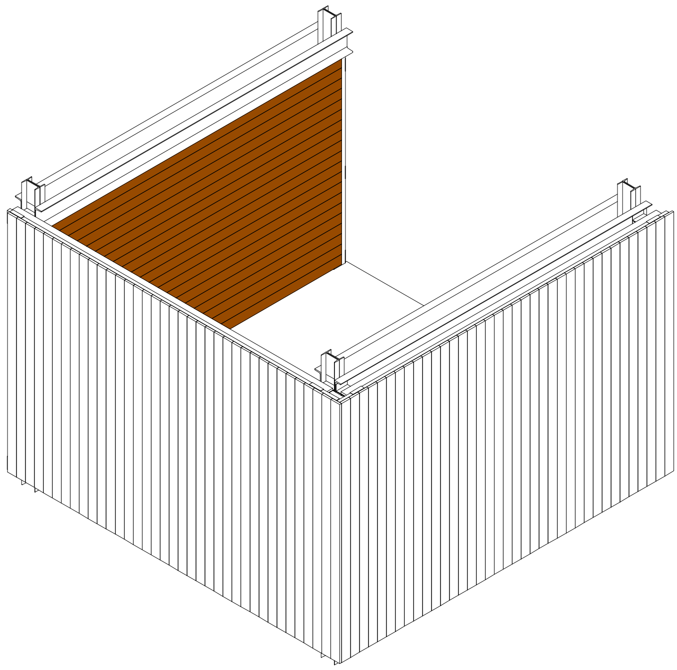
STEP_6
Nailing the polyester bands to the wooden boards, in order to block the insulation



STEP_7
Screwing the boards 120x25 mm in vertical position



STEP_8
Screwing the boards 120x25 mm in horizontal position



Technology assessment

CV_4

REVERSIBILITY

0 10

FLEXIBILITY

0 10

ASSEMBLY/DISASSEMBLY TIME

0 10

ASSEMBLY/DISASSEMBLY EASE

0 10

Environmental comfort

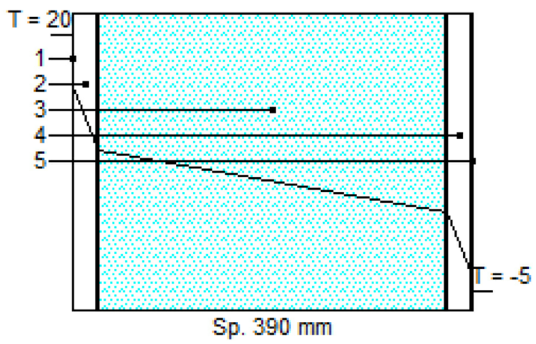
CV_4

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

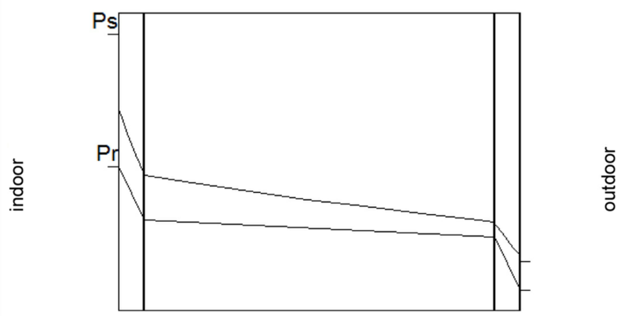
N.	Layer	s [mm]	lambda [W/mK]	C [W/m^2K]	M.S. [kg/m^2]	$P<50*10^{12}$ [kg/msPa]	C.S. [J/kgK]	R [m^2K/W]
1	Indoor addittance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Vertical air layer 340 mm	340	2.125	6.250	0.44	193.000	1008	0.160
4	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
5	Outdoor addittance	0		25.000			0	0.040

RESISTANCE = 0.655 m^2K/W		**TRASMITTANCE** = 1.528 W/m^2K
THICKNESS = 390 mm	**AREIC HEAT CAPACITY** (int) = 19.240 kJ/m^2K	**SURFACE MASS** = 28 kg/m^2
PERIODIC TRAMITTANCE = 1.43 W/m^2K	**MITIGATION FACTOR** = 0.97	**DISPLACEMENT** = 1.49 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

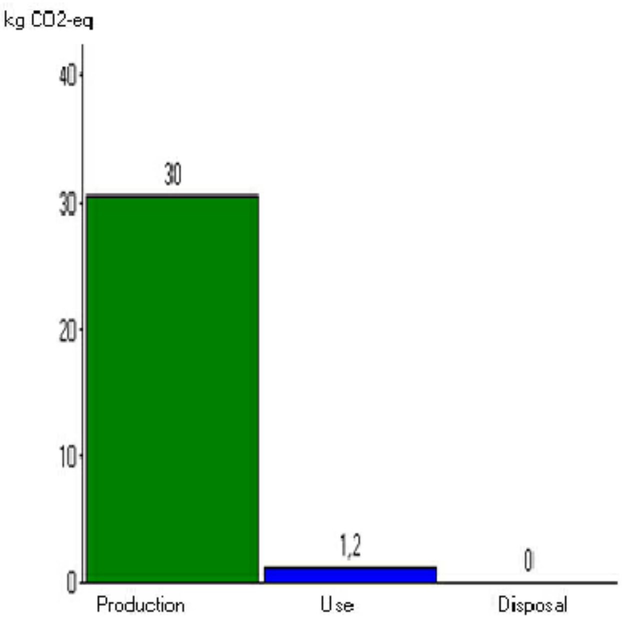


	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]	Te [°C]	Pse [Pa]	Pre [Pa]	URe [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

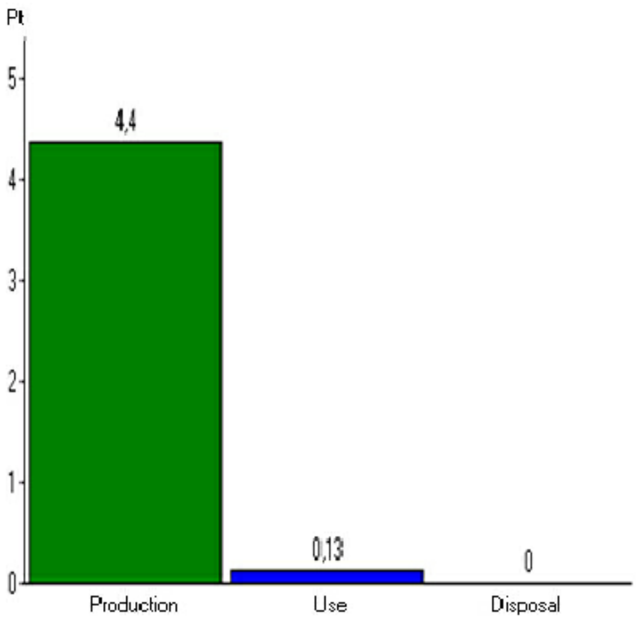
Life Cycle Assessment

CV_4

METHOD IPCC 2007- 31,2 KgCO2-eq



METHOD ReCiPe- 4,53 Pt



Technology assessment

CV_4a

REVERSIBILITY

0 10

ASSEMBLY/DISASSEMBLY TIME

0 10

FLEXIBILITY

0 10

ASSEMBLY/DISASSEMBLY EASE

0 10

Environmental comfort

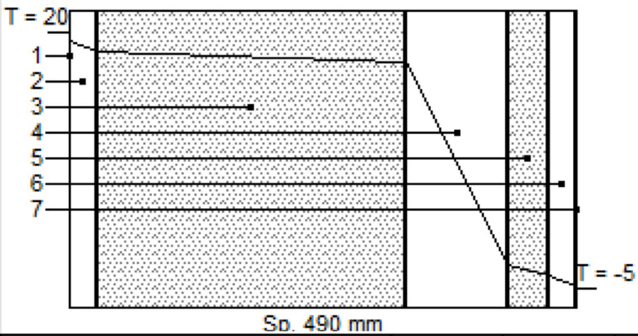
CV_4a

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

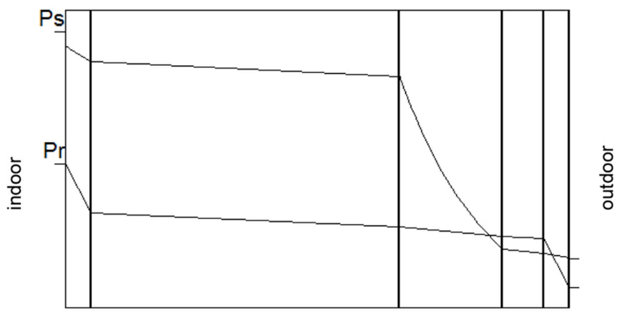
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Indoor adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Vertical air layer 300 mm	300	1.875	6.250	0.39	193.000	1008	0.160
4	Sheep wool insulation	100	0.032	0.318	3.00	96.500	1300	3.145
5	Vertical air layer 40 mm	40	0.250	6.250	0.05	193.000	1008	0.160
6	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
7	Outdoor adduttance	0		25.000			0	0.040

RESISTANCE = 3.959 m²K/W		TRASMITTANCE = 0.253 W/m²K
THICKNESS = 490 mm	AREIC HEAT CAPACITY (int) = 22.965 kJ/m²K	SURFACE MASS = 31 kg/m²
PERIODIC TRAMITTANCE = 0.23 W/m²K	MITIGATION FACTOR = 0.93	DISPLACEMENT = 2.81 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

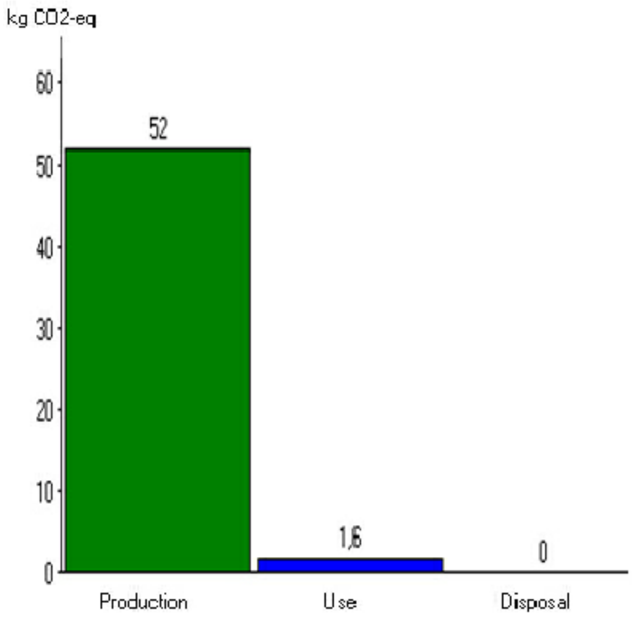


	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]	Te [°C]	Pse [Pa]	Pre [Pa]	URe [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

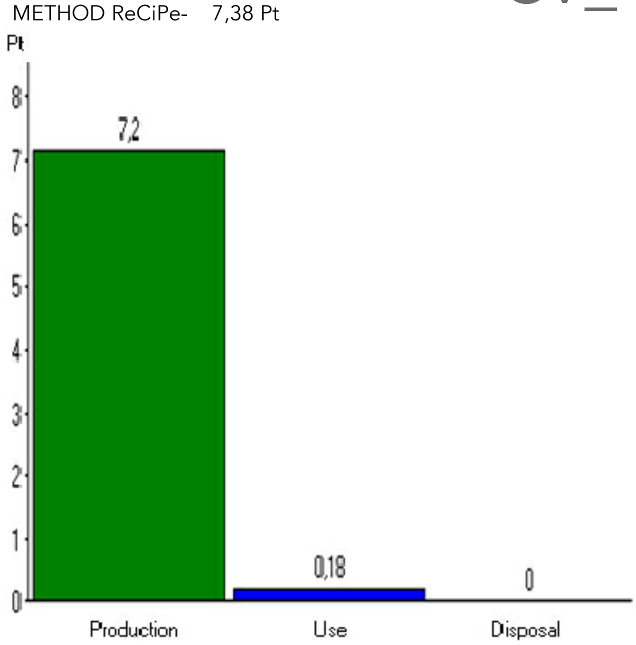
Life Cycle Assessment

CV_4a

METHOD IPCC 2007- 53,6 KgCO2-eq



METHOD ReCiPe- 7,38 Pt



Lower horizontal closure n_1

COi_1

COMPONENTS

Wooden elements

120x25 mm

100x50 mm

200x50 mm

50x50 mm

The length of the boards is uniform

Steel profiles

UPN 240

Steel connections

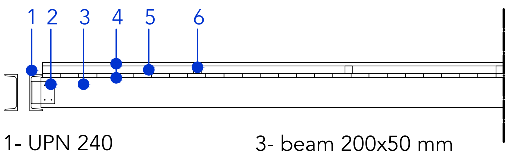
Bracket 150x150 mm

Bolt, nut and locknut

Screw 5x40 mm

Screw 6x80 mm

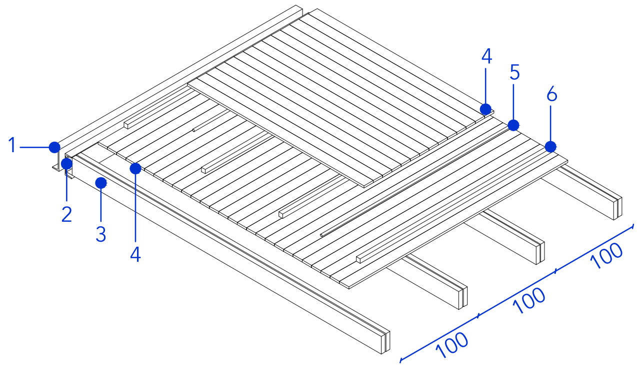
CONSTRUCTIVE DETAIL



1- UPN 240
2- bracket 150mm
3- beam 200x50 mm

3- beam 200x50 mm
4- board 120x25 mm
5- space for installations
6- wooden element 50x50 m

scale 1:50



variation a

COi_1a

COMPONENTS

Wooden elements

120x25 mm

100x50 mm

200x50 mm

50x50 mm

The length of the boards is uniform

Steel connections

Bracket 150x150 mm

Screw 5x40 mm

Bolt, nut and locknut

Screw 6x80 mm

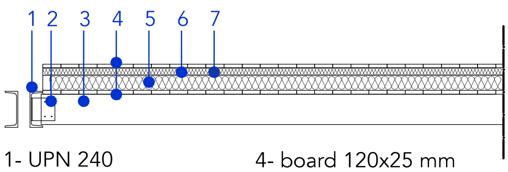
Insulation

Wool insulation
1000xl variable x100/50 mm

Steel profiles

UPN 240

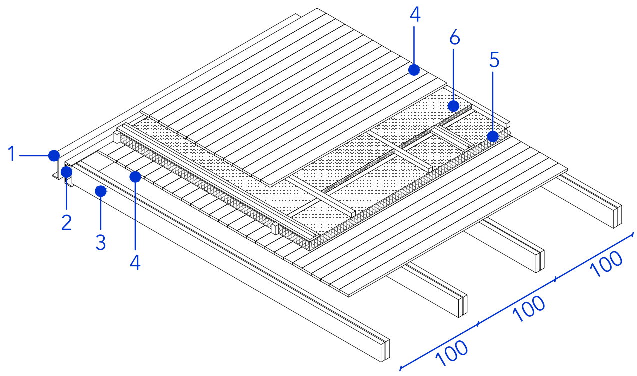
CONSTRUCTIVE DETAIL



1- UPN 240
2- bracket 150mm
3- beam 200x50 mm

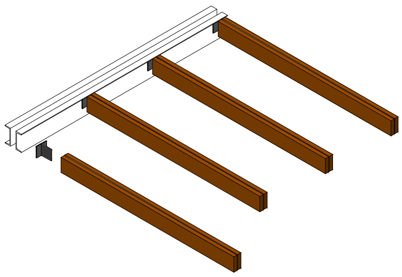
4- board 120x25 mm
5- wool insulation 100 mm
6- wool insulation 50 mm
7- space for installations

scale 1:50

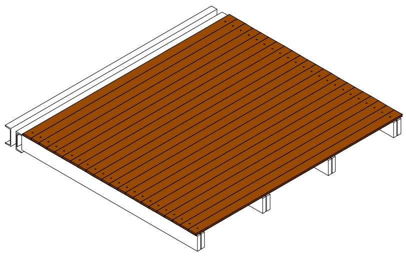


ASSEMBLY STEPS

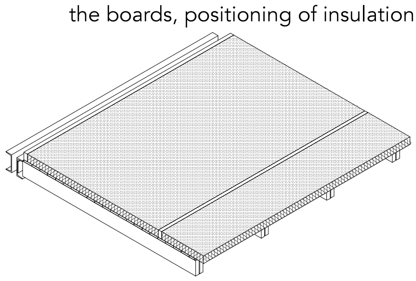
STEP_1
Bolting of the coupled beams to the brackets



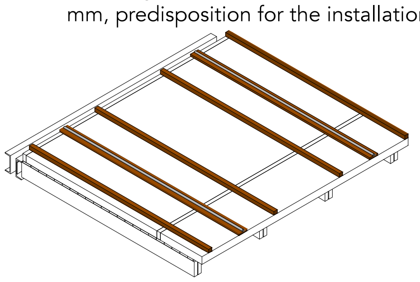
STEP_2
Screwing of the boards to the beams



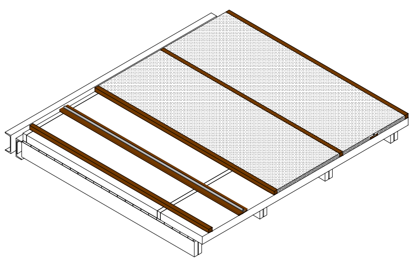
STEP_3
Screwing of the wooden elements to the boards, positioning of insulation



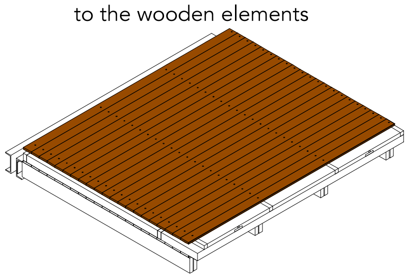
STEP_4
Screwing of the wooden elements 50x50 mm, predisposition for the installations



STEP_5
Positioning of insulation



STEP_6
Screwing of the boards 50x50 mm to the wooden elements



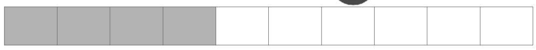
Technology assessment

COi_1

REVERSIBILITY

0 10

ASSEMBLY/DISASSEMBLY TIME



0 10

FLEXIBILITY

0 10

ASSEMBLY/DISASSEMBLY EASE

0 10

Environmental comfort

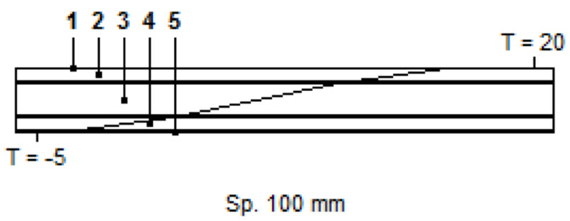
COi_1

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

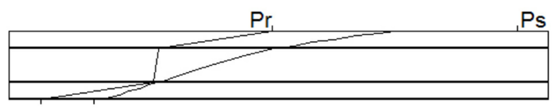
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Higher adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Slightly ventilated horizontal air layer	50	0.200	4.000	0.05	193.000	1008	0.250
4	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
5	Lower adduttance	0		25.000			0	0.040

RESISTANCE = 0.745 m²K/W	**AREIC HEAT CAPACITY** (sup) = 19.226 kJ/m²K	**TRASMITTANCE** = 1.343 W/m²K
THICKNESS = 100 mm	**AREIC HEAT CAPACITY** (inf) = 25.228 kJ/m²K	**SURFACE MASS** = 28 kg/m²
PERIODIC TRAMITTANCE = 1.44 W/m²K	**MITIGATION FACTOR** = 0.97	**DISPLACEMENT** = 1.49 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

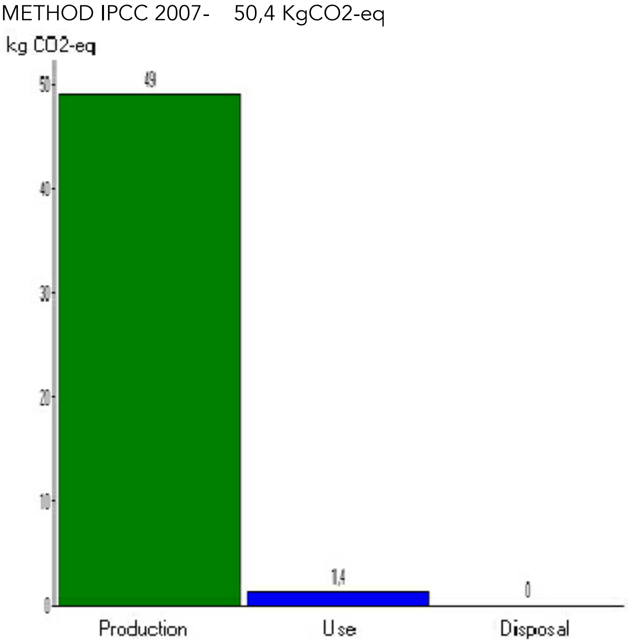


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

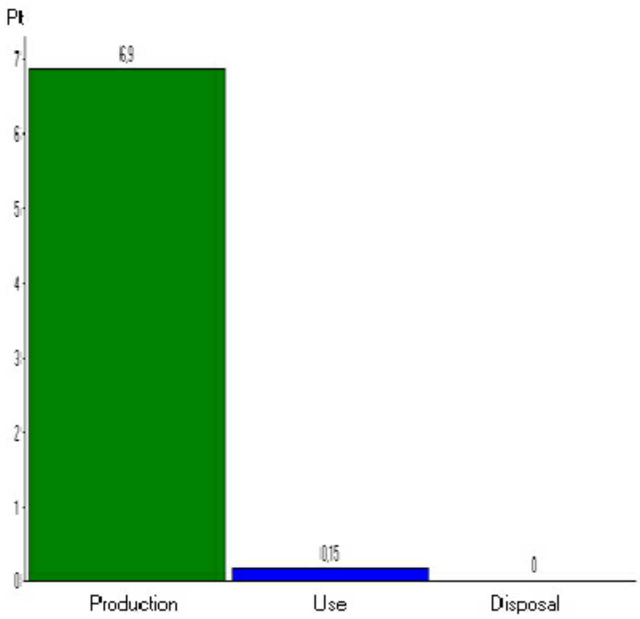
Life Cycle Assessment

COi_1

METHOD IPCC 2007- 50,4 KgCO2-eq



METHOD ReCiPe- 7,05 Pt



Technology assessment

COi_1a

REVERSIBILITY

0 10

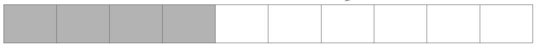
ASSEMBLY/DISASSEMBLY TIME

0 10

FLEXIBILITY

0 10

ASSEMBLY/DISASSEMBLY EASE



0 10

Environmental comfort

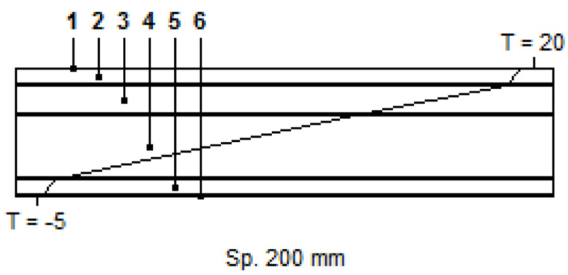
COi_1a

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

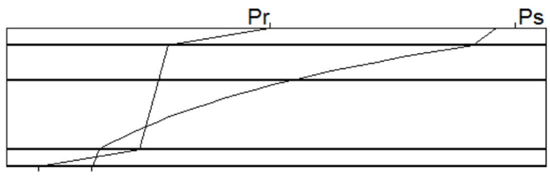
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Higher adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Sheep wool insulation	50	0.032	0.636	1.50	96.500	1300	1.572
4	Sheep wool insulation	100	0.032	0.318	3.00	96.500	1300	3.145
5	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
6	Lower adduttance	0		25.000			0	0.040

RESISTANCE = 5.212 m²K/W	**AREIC HEAT CAPACITY** (sup) = 23.717 kJ/m²K	**TRASMITTANCE** = 0.192 W/m²K
THICKNESS = 200 mm	**AREIC HEAT CAPACITY** (inf) = 25.267 kJ/m²K	**SURFACE MASS** = 32 kg/m²
PERIODIC TRAMITTANCE = 0.17 W/m²K	**MITIGATION FACTOR** = 0.90	**DISPLACEMENT** = 3.49 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

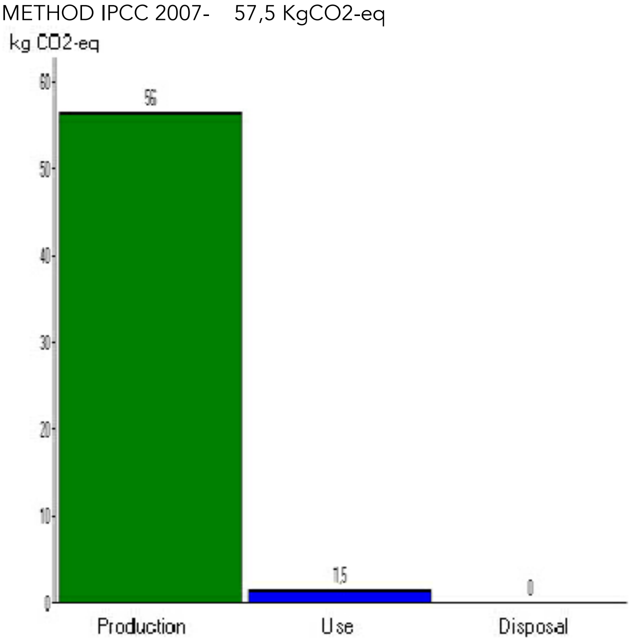


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

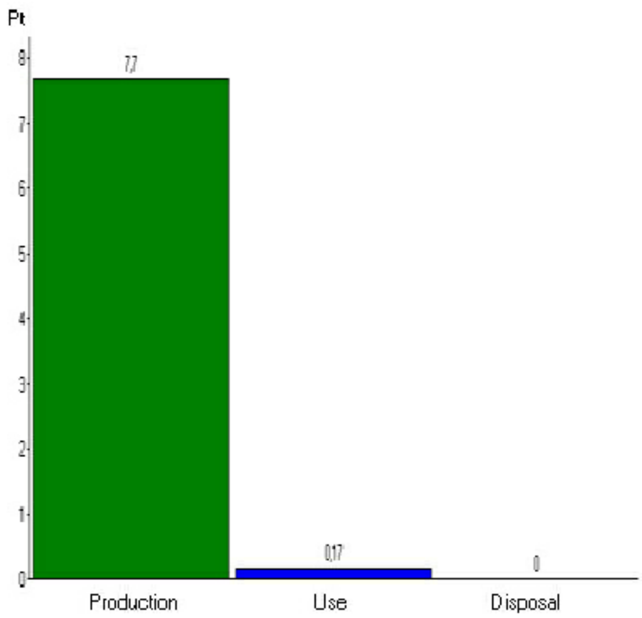
Life Cycle Assessment

COi_1a

METHOD IPCC 2007- 57,5 KgCO2-eq



METHOD ReCiPe- 7,87 Pt



Lower horizontal closure n_2

COi_2

COMPONENTS

Wooden elements

50x50 mm

120x25 mm

300x40 mm

The length of the boards is uniform

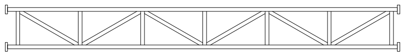
Steel connections

Screw 5x40 mm

Screw 8x90 mm

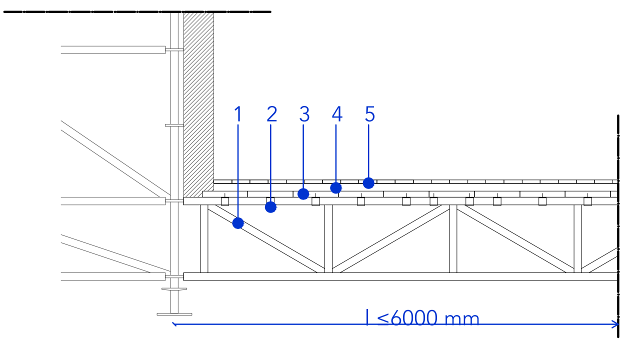
Omega connector with screws

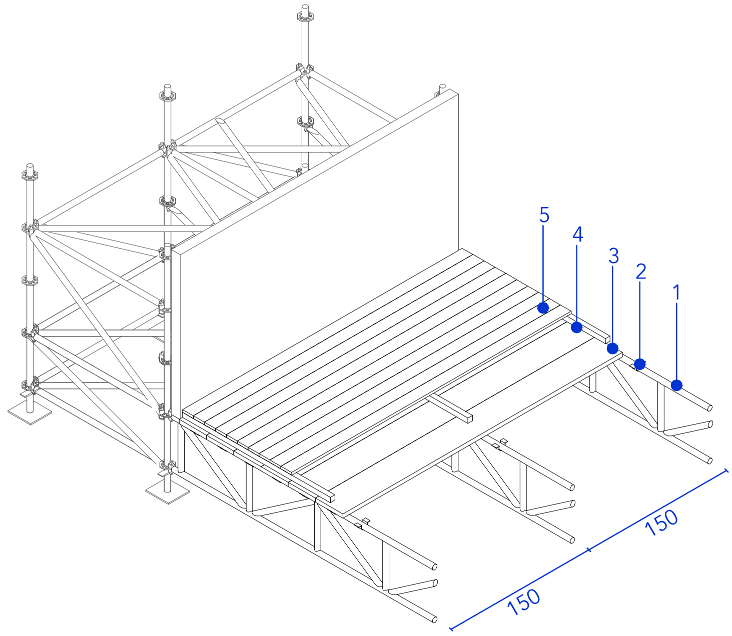
Multicom elements



Truss beam, h 500mm, l ≤6000 mm

CONSTRUCTIVE DETAIL





1- truss beam
2- omega connector
3- board 300x40 mm
4- wooden element 50x50 mm,
5- board 120x25 mm

scale 1:50

variation a

COi_2a

COMPONENTS

Wooden elements

50x50 mm

120x25 mm

300x40 mm

The length of the boards is uniform

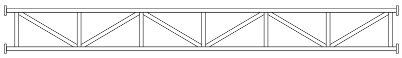
Steel connections

Screw 5x40 mm

Screw 8x90 mm

Omega connector with screws

Multicom elements



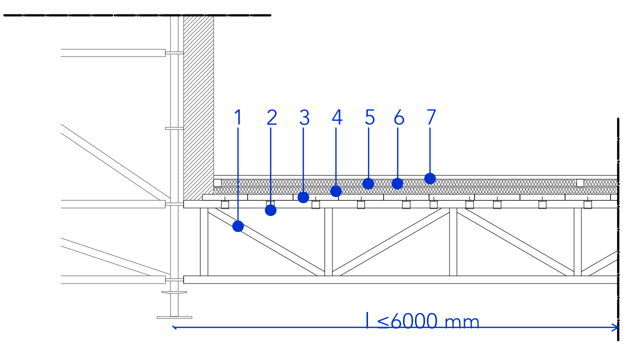
Truss beam, h 500mm, l ≤6000 mm

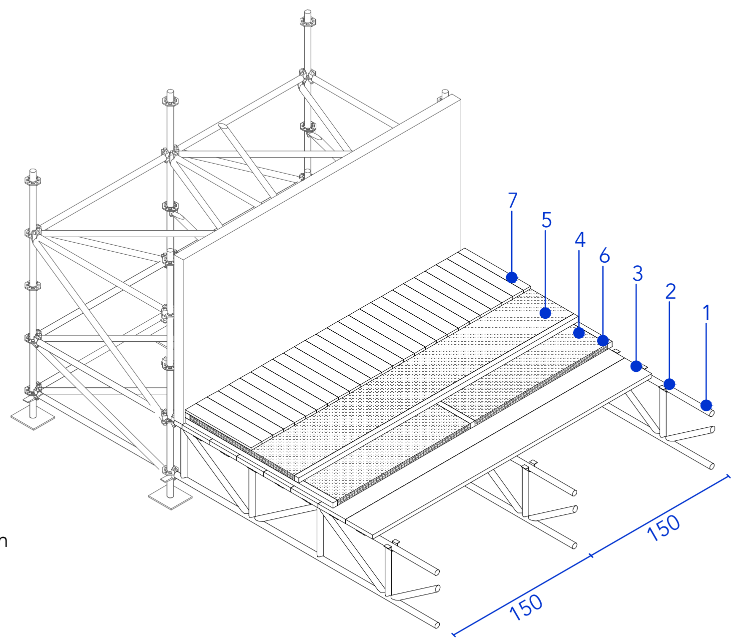
Insulation

Sheep wool 1000x l variable x50 mm

Sheep wool 1400x l ≤6000 mm x50 mm

CONSTRUCTIVE DETAIL



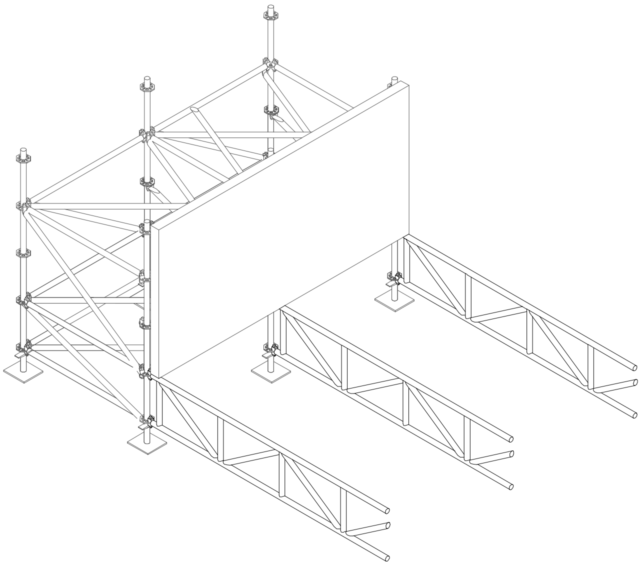


1- truss beam
2- omega connector
3- board 300x40 mm
4- wool insulation 1400x l ≤6000 mm x50 mm
5- wool insulation 1000x l ≤6000 mm x50 mm
6- wooden element 50x50 mm
7- board 120x25 mm

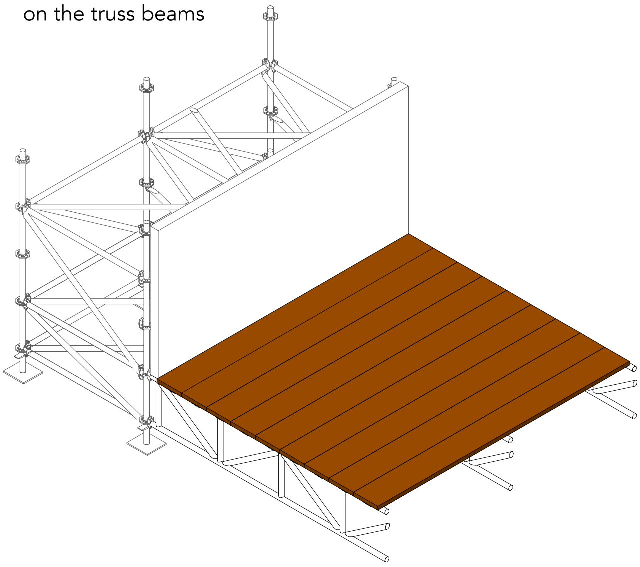
scale 1:50

ASSEMBLY STEPS

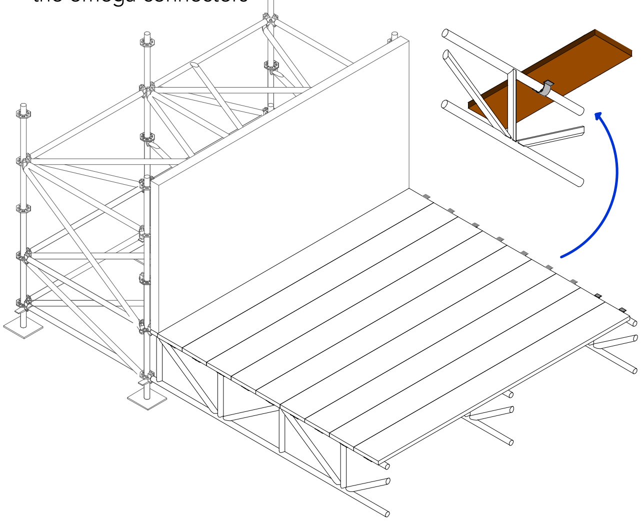
STEP_1
Assembly of the truss beams



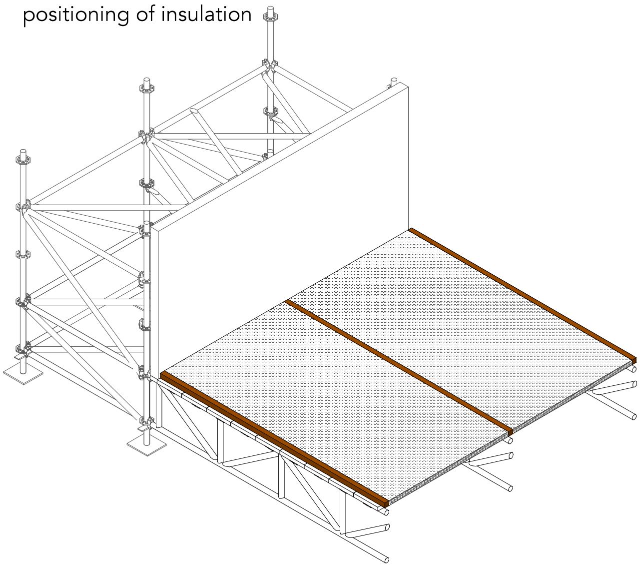
STEP_2
Positioning of the wooden boards on the truss beams



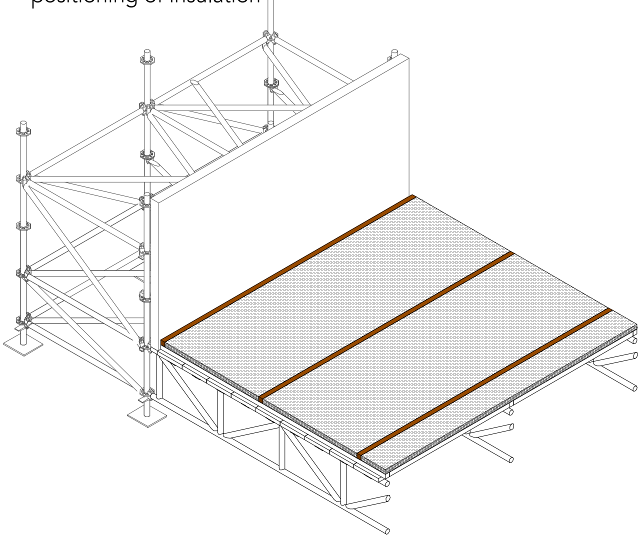
STEP_3
Connection of the wooden boards to the truss beams through the omega connectors



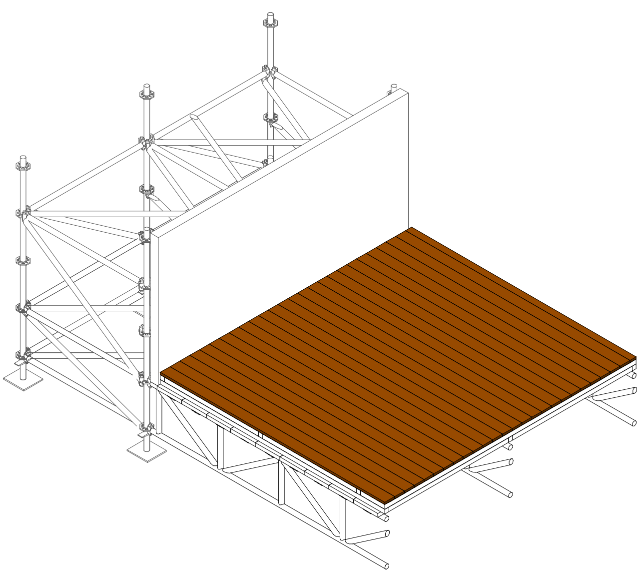
STEP_4
Screwing of the wooden elements to the boards, positioning of insulation



STEP_5
Screwing of the wooden element to the underlying wooden elements, positioning of insulation



STEP_6
Screwing of the wooden boards to the wooden elements



Technology assessment

COi_2

REVERSIBILITY

0 10

ASSEMBLY/DISASSEMBLY TIME

0 10

FLEXIBILITY

0 10

ASSEMBLY/DISASSEMBLY EASE

0 10

Environmental comfort

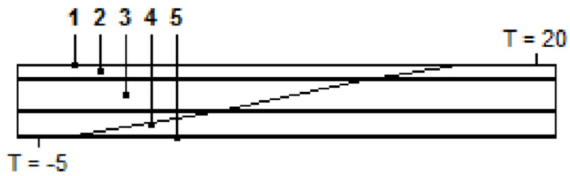
COi_2

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Higher adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Slightly ventilated orizontal air layer	50	0.200	4.000	0.05	193.000	1008	0.250
4	Pine boards	40	0.154	3.850	22.00	4.500	1660	0.260
5	Lower adduttance	0		25.000			0	0.040

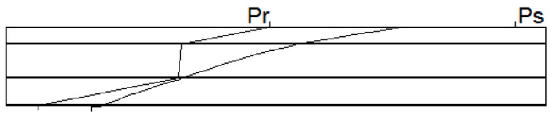
RESISTANCE = 0.842 m²K/W	**AREIC HEAT CAPACITY** (sup) = 23.289 kJ/m²K	**TRASMITTANCE** = 1.188 W/m²K
THICKNESS = 115 mm	**AREIC HEAT CAPACITY** (inf) = 32.903 kJ/m²K	**SURFACE MASS** = 36 kg/m²
PERIODIC TRAMITTANCE = 1.21 W/m²K	**MITIGATION FACTOR** = 0.94	**DISPLACEMENT** = 2.17 h

STRUCTURE



Sp. 115 mm

DIAGRAMS OF THE PRESSURES

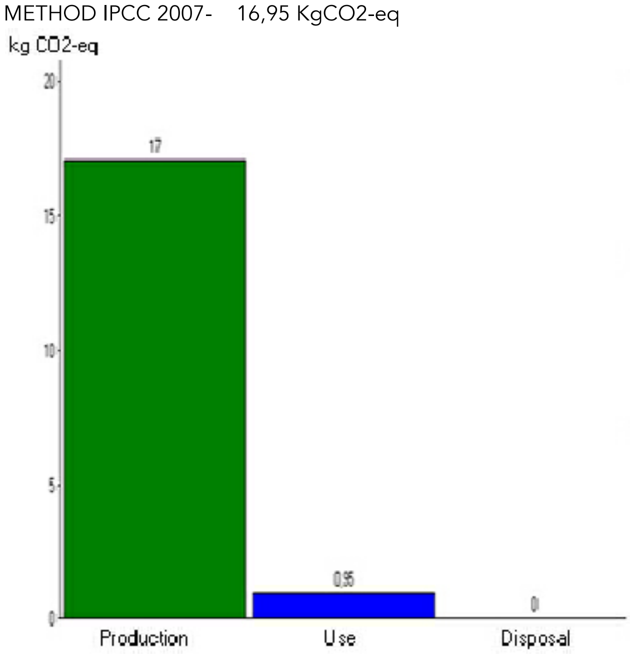


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

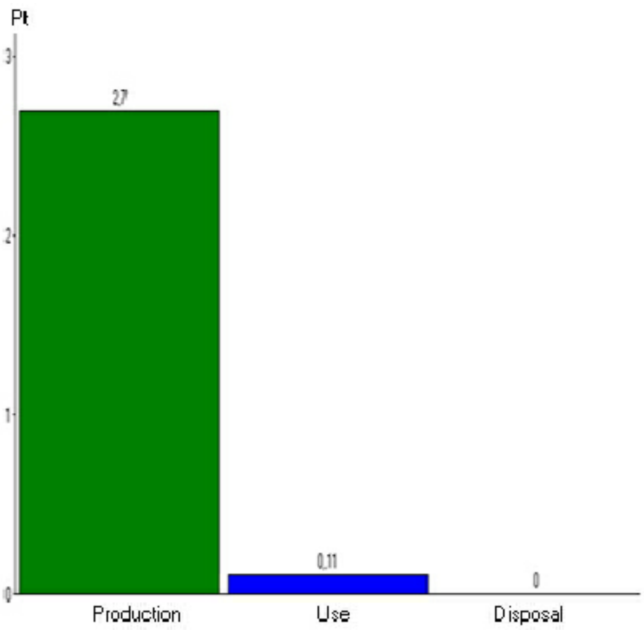
Life Cycle Assessment

COi_2

METHOD IPCC 2007- 16,95 KgCO2-eq



METHOD ReCiPe- 2,71 Pt

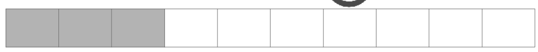


Technology assessment

COi_2a

REVERSIBILITY

ASSEMBLY/DISASSEMBLY TIME



FLEXIBILITY

ASSEMBLY/DISASSEMBLY EASE

Environmental comfort

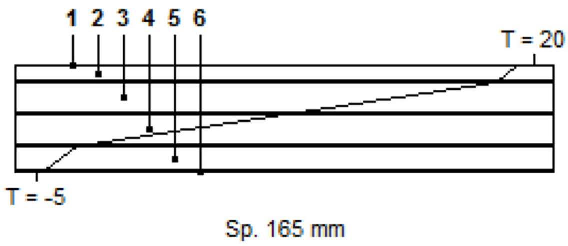
COi_2a

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

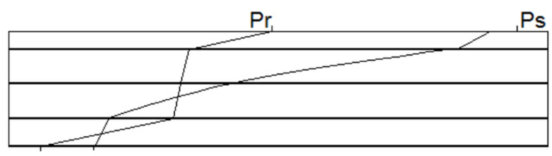
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Higher adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Sheep wool insulation	50	0.032	0.636	1.50	96.500	1300	1.572
4	Sheep wool insulation	50	0.032	0.636	1.50	96.500	1300	1.572
5	Pine boards	40	0.154	3.850	22.00	4.500	1660	0.260
6	Lower adduttance	0		25.000			0	0.040

RESISTANCE = 3.737 m²K/W	**AREIC HEAT CAPACITY** (sup) = 23.579 kJ/m²K	**TRASMITTANCE** = 0.268 W/m²K
THICKNESS = 165 mm	**AREIC HEAT CAPACITY** (inf) = 35.432 kJ/m²K	**SURFACE MASS** = 39 kg/m²
PERIODIC TRAMITTANCE = 0.24 W/m²K	**MITIGATION FACTOR** = 0.89	**DISPLACEMENT** = 3.56 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

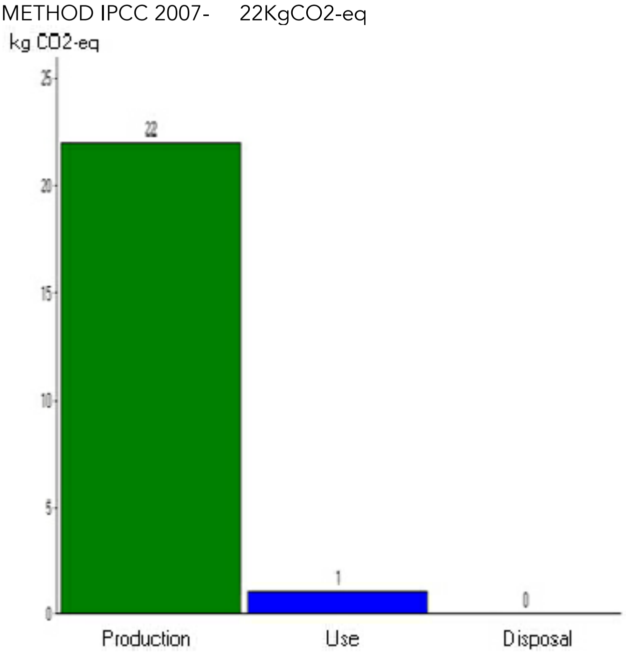


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

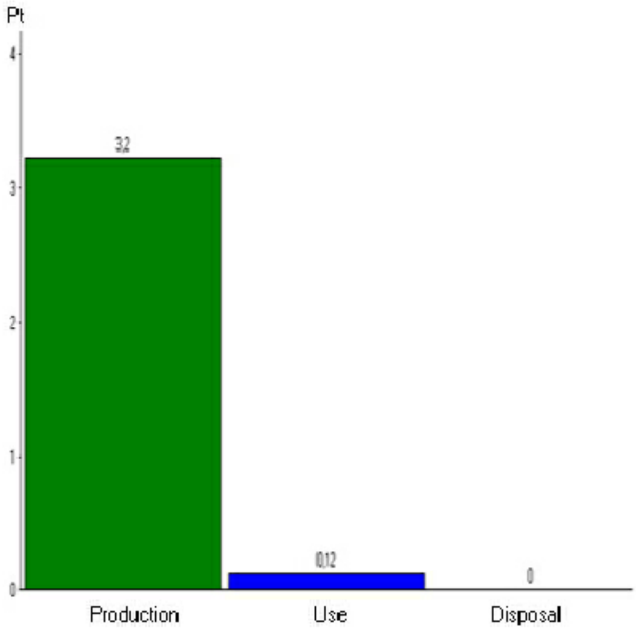
Life Cycle Assessment

COi_2a

METHOD IPCC 2007- 22KgCO2-eq



METHOD ReCiPe- 3,22 Pt



Lower horizontal closure n_3

COi_3

COMPONENTS

Wooden elements

- 50x50 mm
- 120x25 mm
- 200x50 mm

The length of the boards is uniform

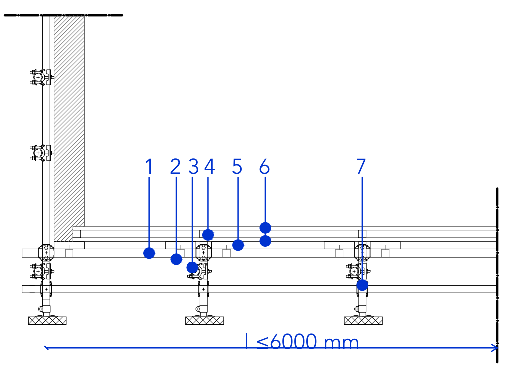
Steel connections

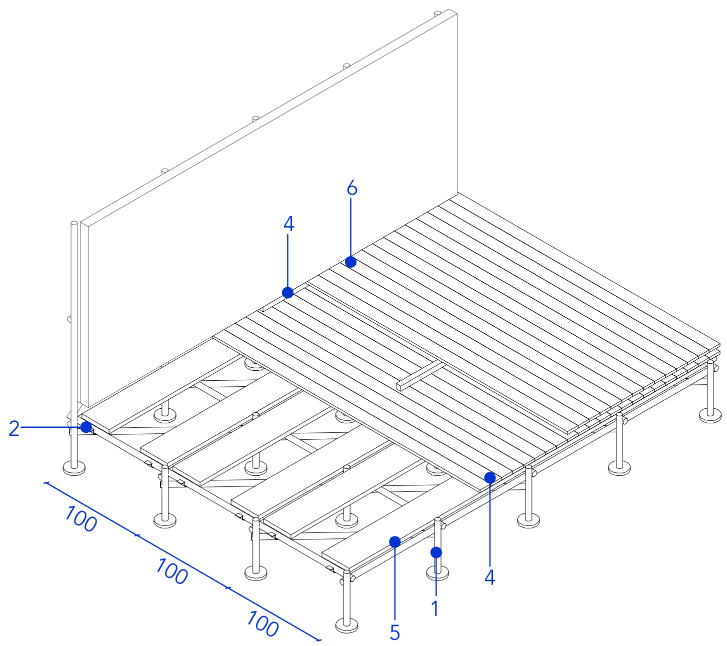
- Screw 5x40 mm
- Screw 8x90 mm
- Omega connector with screws

Tubular-joint system

- Tubular element, l variable
- Base plate
- Right angle clamp
- Swivel clamp

CONSTRUCTIVE DETAIL





1- tubular element
2- omega connector
3- right angle clamp
4- wooden element 50x50 mm
5- board 200x50 mm
6- board 120x25 mm
7- swivel clamp

scale 1:50

variation a

COi_3a

COMPONENTS

Wooden elements

- 50x50 mm
- 120x25 mm
- 200x50 mm

Steel connections

- Screw 5x40 mm
- Screw 8x90 mm
- Omega connector with screws

Tubular-joint system

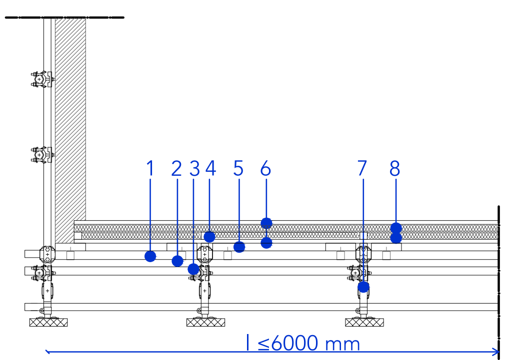
- Tubular element, l variable
- Base plate
- Right angle clamp
- Swivel clamp

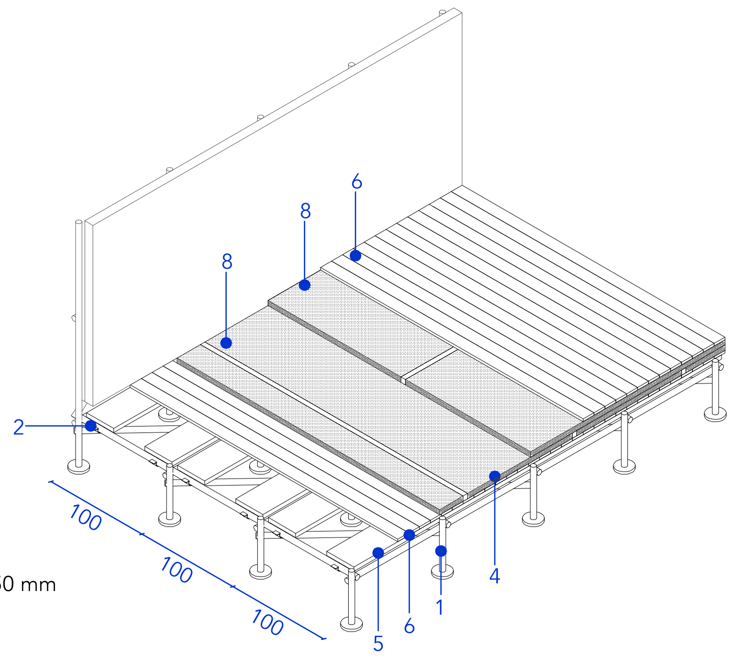
Insulation

- Sheep wool 950x l variable x50 mm

The length of the boards is uniform

CONSTRUCTIVE DETAIL





1- tubular element
2- omega connector
3- right angle clamp
4- wooden element 50x50 mm
5- board 200x50 mm
6- board 120x25 mm
7- swivel clamp
8- wool insulation
950 x l variable x 50 mm

scale 1:50

variation b

COi_3b

COMPONENTS

Wooden elements

- 50x50 mm
- 120x25 mm
- 200x50 mm

The length of the boards is uniform

Steel connections

- Screw 5x40 mm
- Screw 8x90 mm
- Bolt, nut and locknut

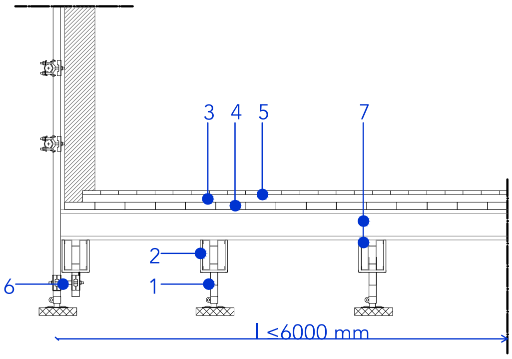
Tubular-joint system

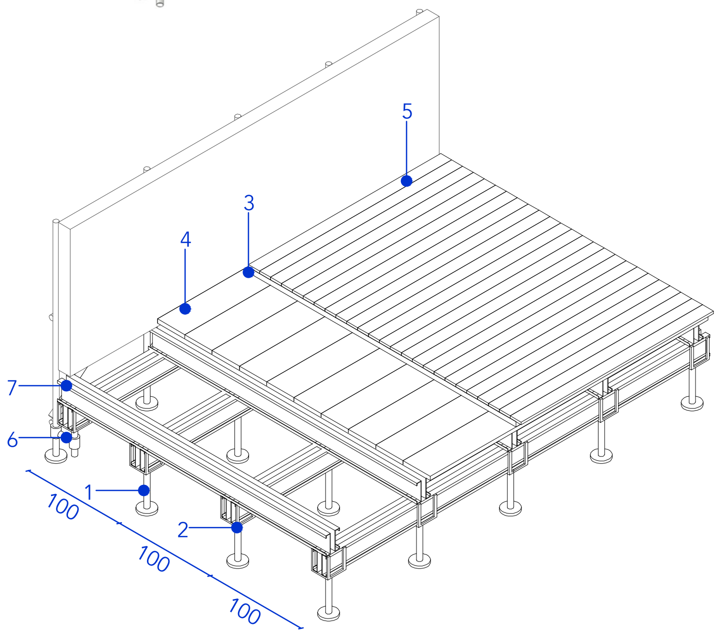
- Tubular element, l variable
- Base plate

Multicom elements

- Cross head
- Parallel joint
- C Profile, h 200 mm

CONSTRUCTIVE DETAIL





1- tubular element
2- cross head
3- wooden element 50x50 mm
4- board 200x50 mm
5- board 120x25 mm
6- parallel joint
7- C profile

scale 1:50

variation c

COi_3c

COMPONENTS

Wooden elements

- 50x50 mm
- 120x25 mm
- 200x50 mm

The length of the boards is uniform

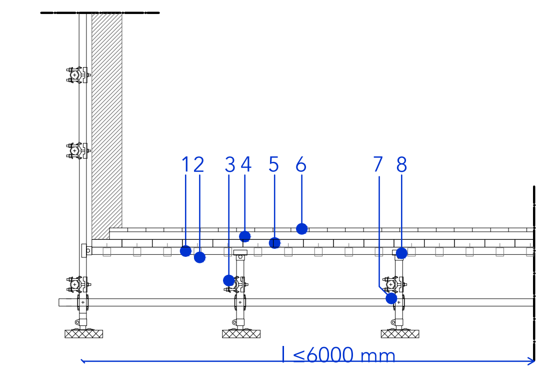
Steel connections

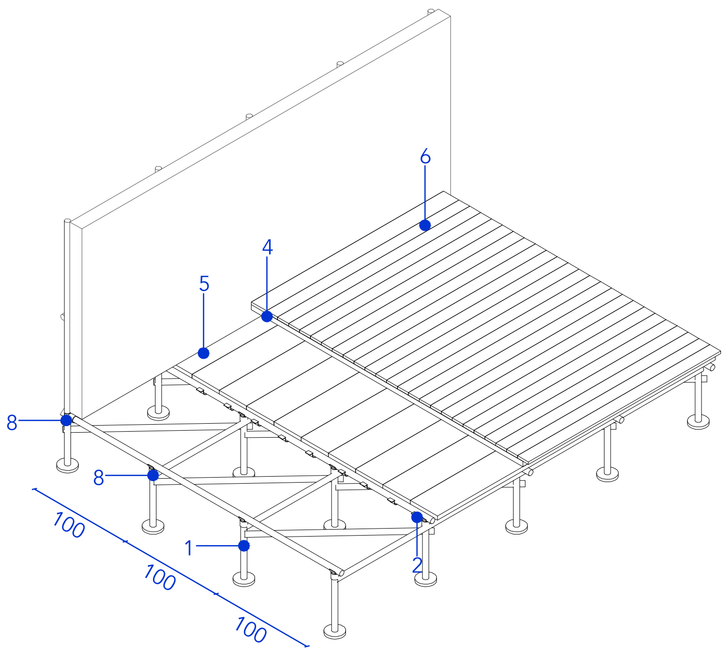
- Screw 5x40 mm
- Screw 8x90 mm
- Omega connector with screws

Tubular-joint system

- Tubular element, l variable
- Base plate
- End joint
- Right angle clamp
- Swivel clamp

CONSTRUCTIVE DETAIL



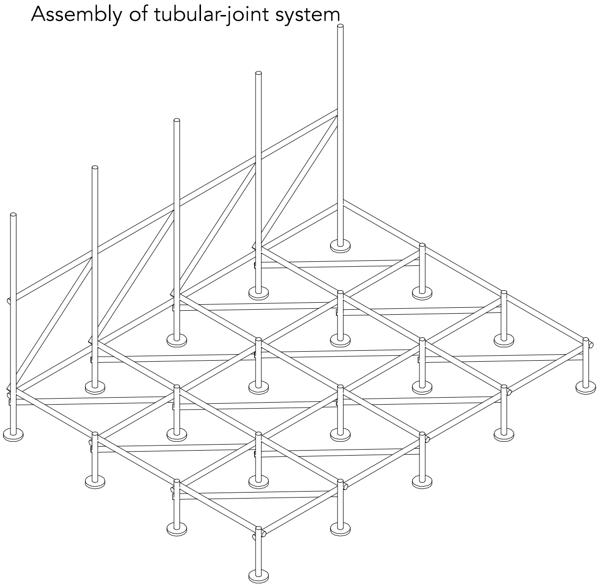


1- tubular element
2- omega connector
3- right angle clamp
4- wooden element 50x50 mm
5- board 200x50 mm
6- board 120x25 mm
7- swivel clamp
8- end joint

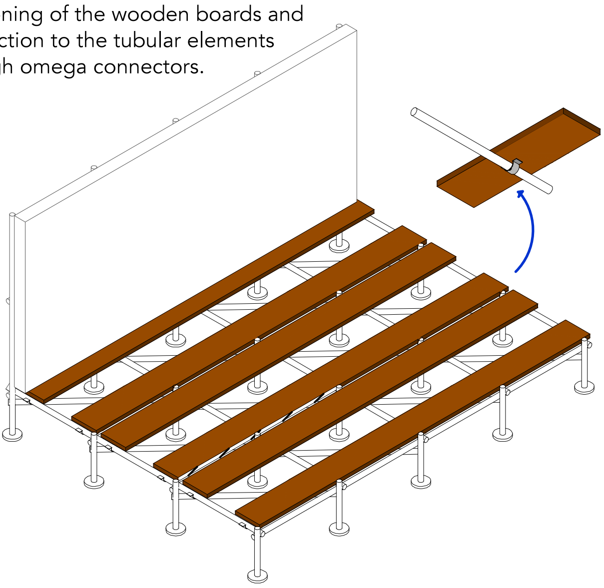
scale 1:50

ASSEMBLY STEPS

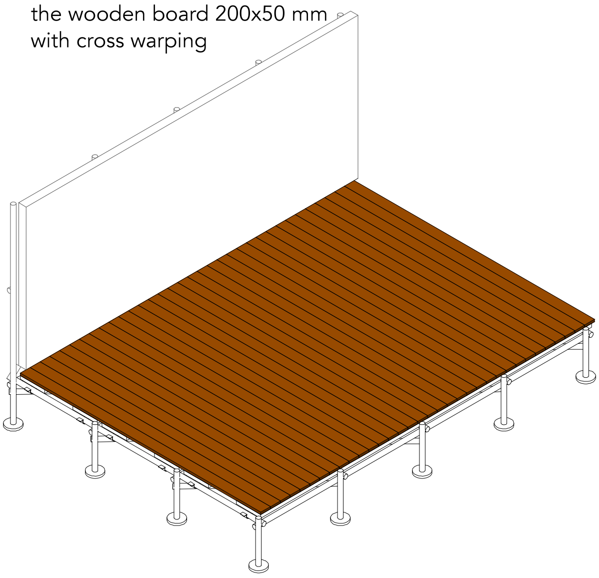
STEP_1
Assembly of tubular-joint system



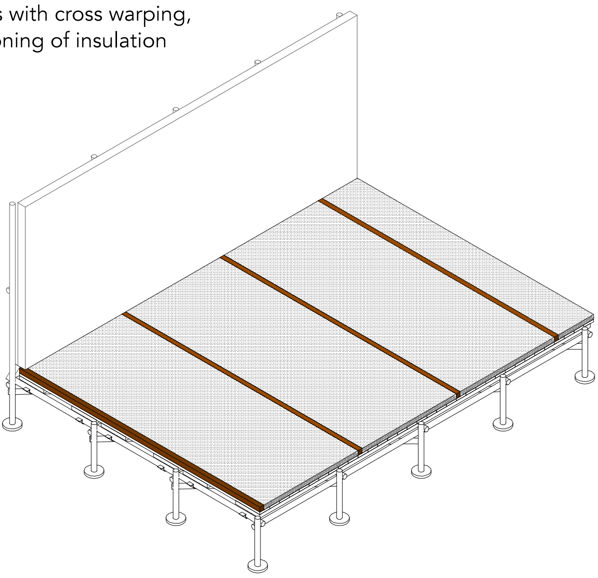
STEP_2
Positioning of the wooden boards and connection to the tubular elements through omega connectors.



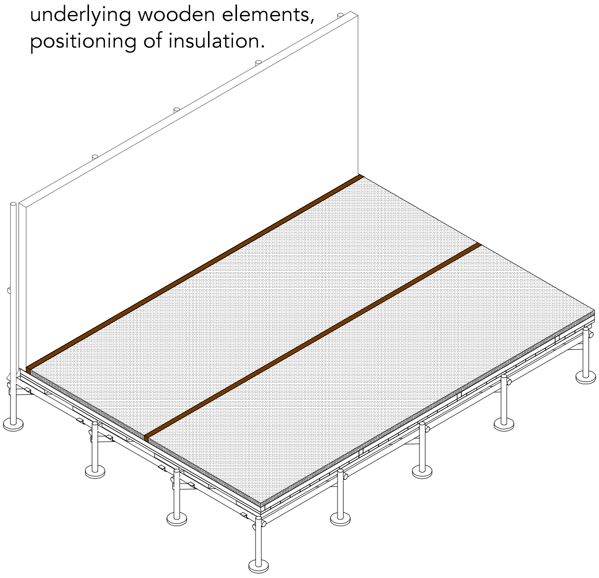
STEP_3
Screwing of the wooden board 120 x25 mm to the wooden board 200x50 mm with cross warping



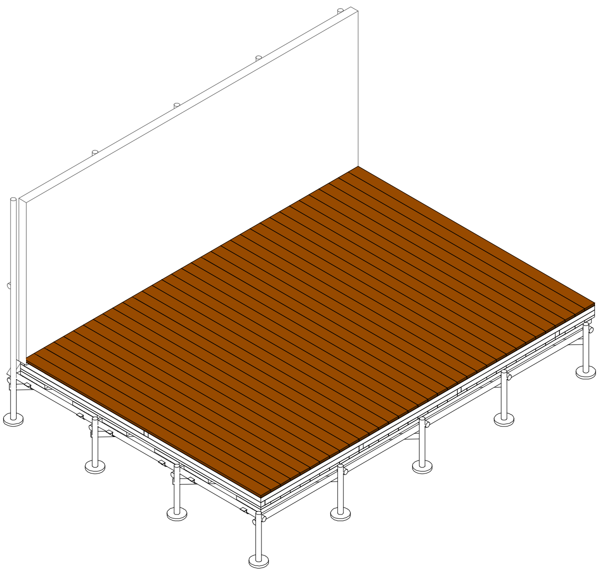
STEP_4
Screwing of the wooden elements to the boards with cross warping, positioning of insulation



STEP_5
Screwing of the wooden elements to the underlying wooden elements, positioning of insulation.



STEP_6
Screwing of the boards to the wooden elements



Technology assessment

COi_3

REVERSIBILITY

0 10

ASSEMBLY/DISASSEMBLY TIME

0 10

FLEXIBILITY

0 10

ASSEMBLY/DISASSEMBLY EASE

0 10

Environmental comfort

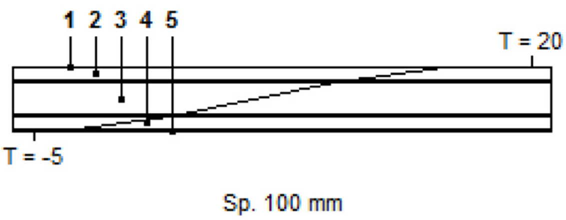
COi_3

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

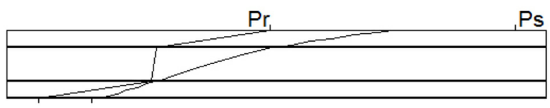
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Higher addúttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Slightly ventilated horizontal air layer	50	0.200	4.000	0.05	193.000	1008	0.250
4	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
5	Lower addúttance	0		25.000			0	0.040

RESISTANCE = 0.745 m²K/W	**AREIC HEAT CAPACITY** (sup) = 19.226 kJ/m²K	**TRASMITTANCE** = 1.343 W/m²K
THICKNESS = 100 mm	**AREIC HEAT CAPACITY** (inf) = 25.228 kJ/m²K	**SURFACE MASS** = 28 kg/m²
PERIODIC TRAMITTANCE = 1.44 W/m²K	**MITIGATION FACTOR** = 0.97	**DISPLACEMENT** = 1.49 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

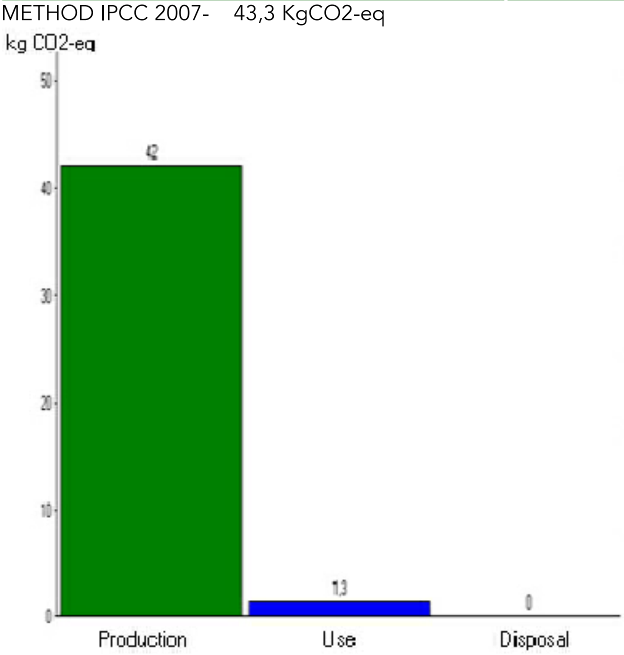


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

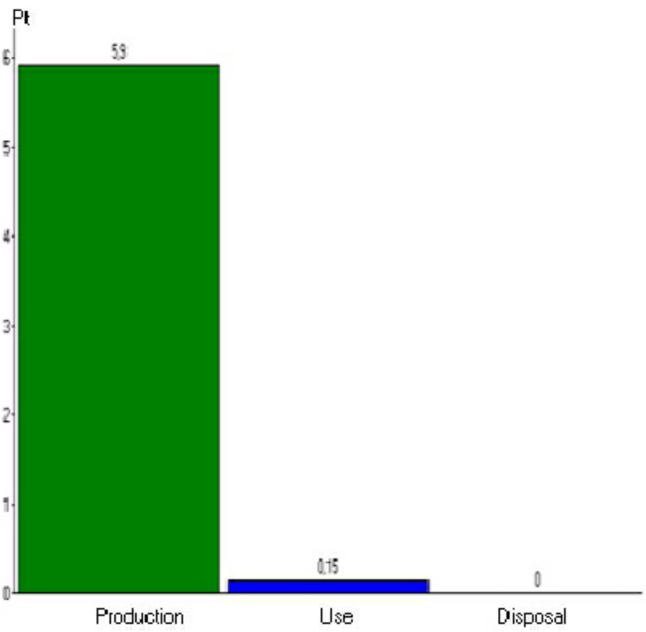
Life Cycle Assessment

COi_3

METHOD IPCC 2007- 43,3 KgCO2-eq



METHOD ReCiPe- 6,05 Pt



Technology assessment

COi_3a

REVERSIBILITY

ASSEMBLY/DISASSEMBLY TIME

FLEXIBILITY

ASSEMBLY/DISASSEMBLY EASE

Environmental comfort

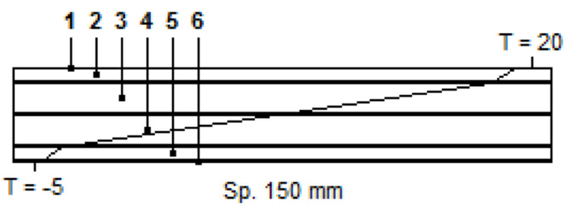
COi_3a

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

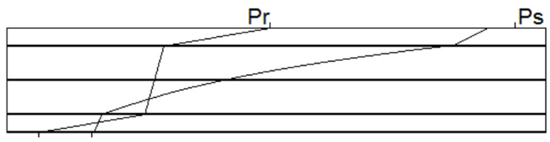
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Higher adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Sheep wool insulation	50	0.032	0.636	1.50	96.500	1300	1.572
4	Sheep wool insulation	50	0.032	0.636	1.50	96.500	1300	1.572
5	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
6	Lower adduttance	0		25.000			0	0.040

RESISTANCE = 3.639 m²K/W	**AREIC HEAT CAPACITY** (sup) = 22.941 kJ/m²K	**TRASMITTANCE** = 0.275 W/m²K
THICKNESS = 150 mm	**AREIC HEAT CAPACITY** (inf) = 24.720 kJ/m²K	**SURFACE MASS** = 31 kg/m²
PERIODIC TRAMITTANCE = 0.26 W/m²K	**MITIGATION FACTOR** = 0.93	**DISPLACEMENT** = 2.69 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

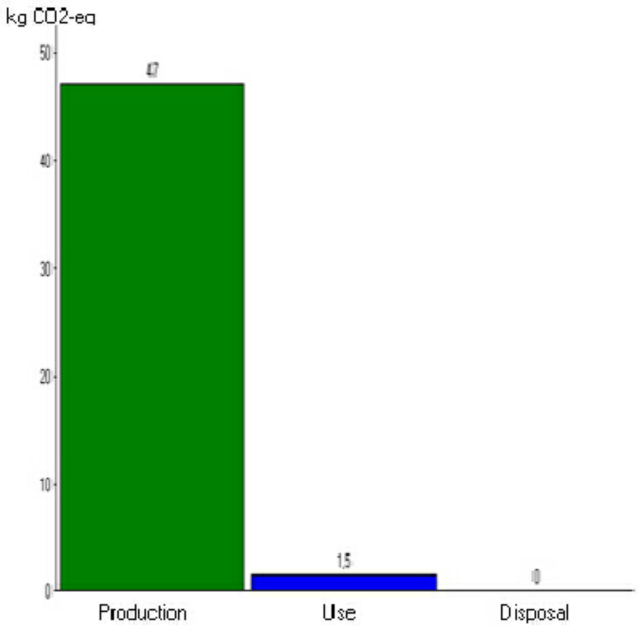


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

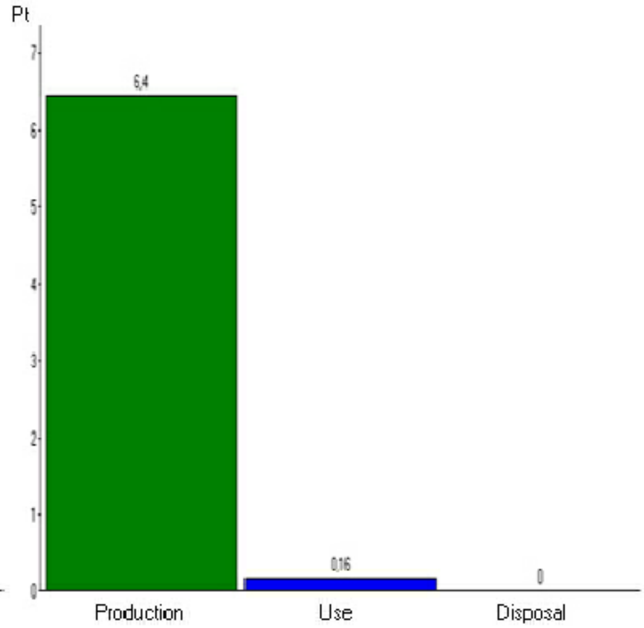
Life Cycle Assessment

COi_3a

METHOD IPCC 2007- 48,5 KgCO2-eq

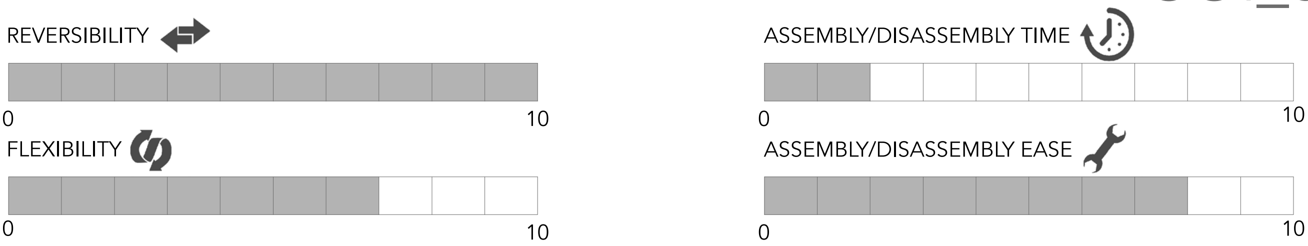


METHOD ReCiPe- 6,56 Pt



Technology assessment

COi_3b



Environmental comfort

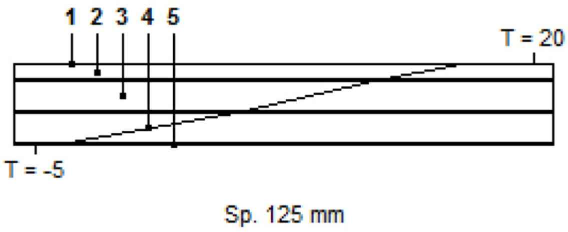
COi_3b

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

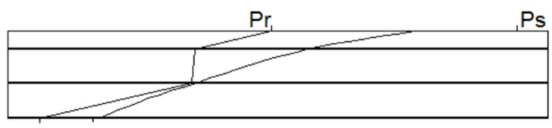
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Higher adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Slightly ventilated horizontal air layer	50	0.200	4.000	0.05	193.000	1008	0.250
4	Pine boards	50	0.154	3.080	27.50	4.500	1660	0.325
5	Lower adduttance	0		25.000			0	0.040

RESISTANCE = 0.907 m²K/W	**AREIC HEAT CAPACITY** (sup) = 25.797 kJ/m²K	**TRASMITTANCE** = 1.103 W/m²K
THICKNESS = 125 mm	**AREIC HEAT CAPACITY** (inf) = 37.052 kJ/m²K	**SURFACE MASS** = 41 kg/m²
PERIODIC TRAMITTANCE = 1.08 W/m²K	**MITIGATION FACTOR** = 0.90	**DISPLACEMENT** = 2.70 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

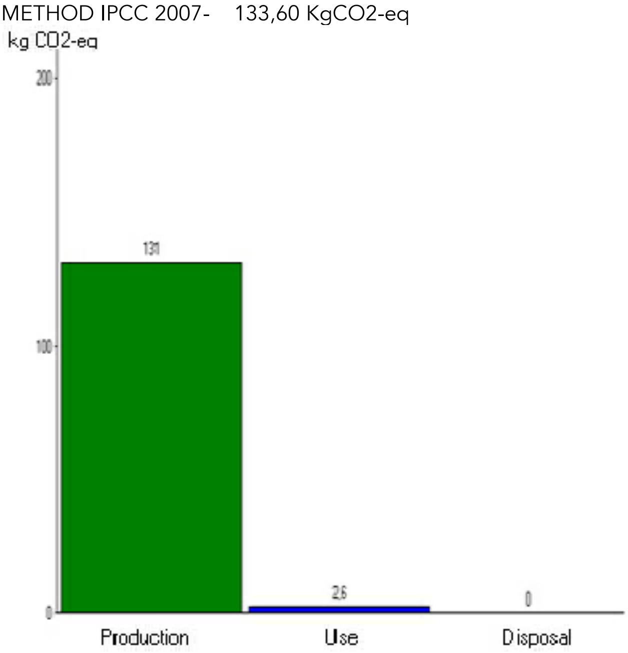


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

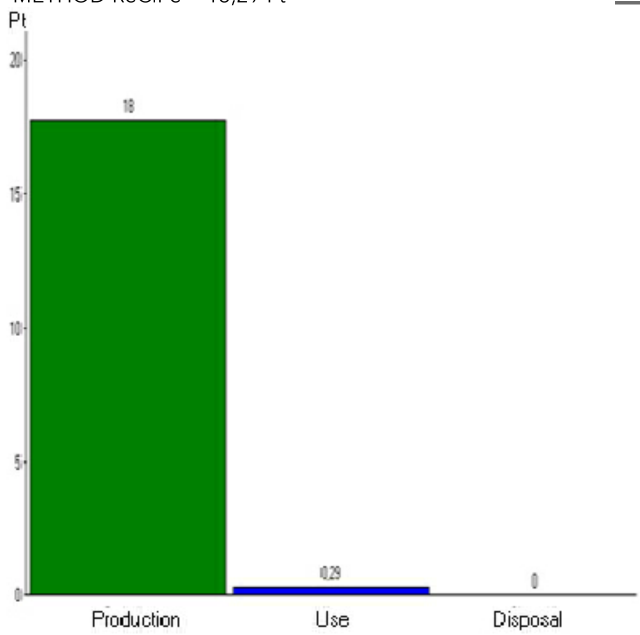
Life Cycle Assessment

COi_3b

METHOD IPCC 2007- 133,60 KgCO2-eq



METHOD ReCiPe- 18,29 Pt



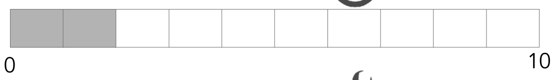
Technology assessment

COi_3c

REVERSIBILITY

FLEXIBILITY

ASSEMBLY/DISASSEMBLY TIME



ASSEMBLY/DISASSEMBLY EASE

Environmental comfort

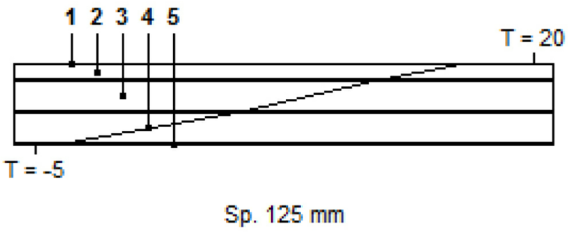
COi_3c

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

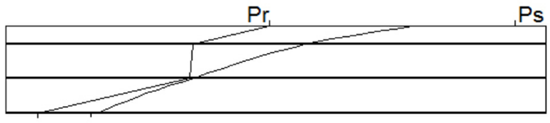
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Higher adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Slightly ventilated horizontal air layer	50	0.200	4.000	0.05	193.000	1008	0.250
4	Pine boards	50	0.154	3.080	27.50	4.500	1660	0.325
5	Lower adduttance	0		25.000			0	0.040

RESISTANCE = 0.907 m²K/W	**AREIC HEAT CAPACITY**(sup) = 25.797 kJ/m²K	**TRASMITTANCE** = 1.103 W/m²K
THICKNESS = 125 mm	**AREIC HEAT CAPACITY** (inf) = 37.052 kJ/m²K	**SURFACE MASS** = 41 kg/m²
PERIODIC TRAMITTANCE = 1.08 W/m²K	**MITIGATION FACTOR** = 0.90	**DISPLACEMENT** = 2.70 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

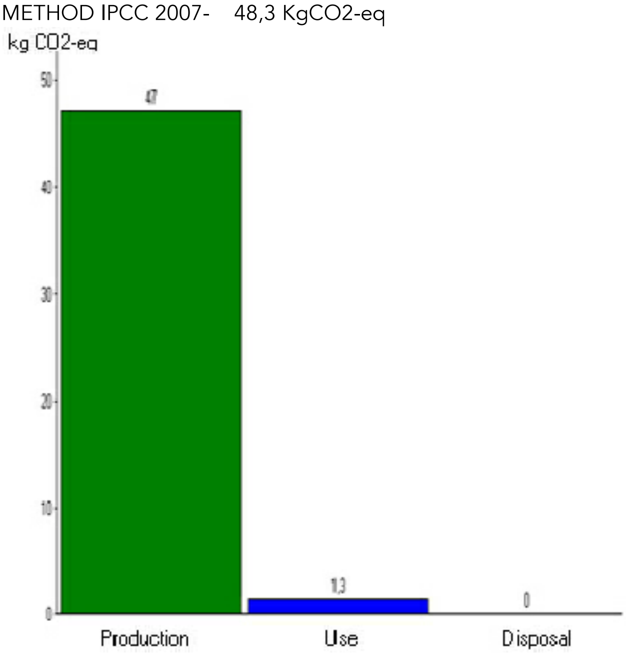


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

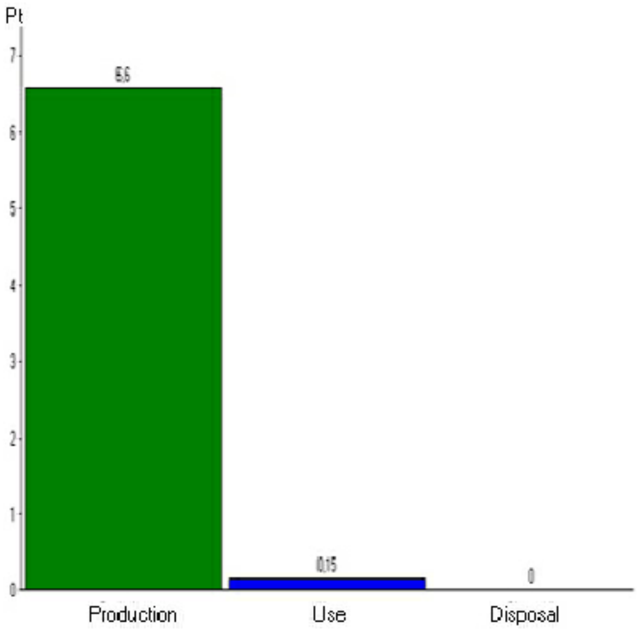
Life Cycle Assessment

COi_3c

METHOD IPCC 2007- 48,3 KgCO2-eq



METHOD ReCiPe- 6,75 Pt



Upper horizontal closure n_1

COs_1

COMPONENTS

Wooden elements

- 120x25 mm
- 50x50 mm
- 200x50 mm

Steel connections

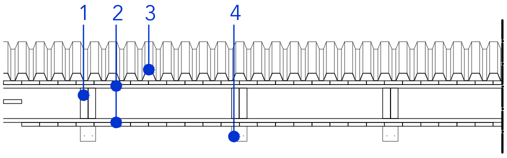
- Bracket 200x200 mm
- Bolt, nut and locknut
- Screw 8x100 mm
- Screw 5x40 mm

Sheet

- Corrugated sheet h 50 mm, distance 250 mm

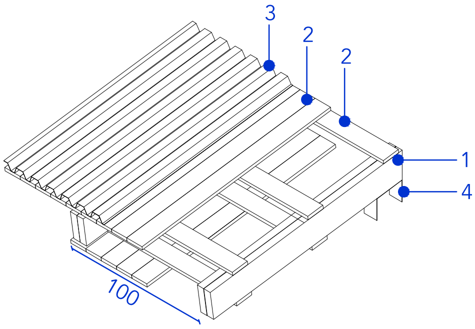
The length of the boards is uniform

CONSTRUCTIVE DETAIL



1- beam 200x50 mm
2- board 120x25 mm
3- corrugated sheet
4- bracket for beams

scale 1:50



variation a

COs_1a

COMPONENTS

Wooden elements

- 50x50 mm
- 120x25 mm
- 200x50 mm

Steel connections

- Bracket 200x200 mm
- Hook
- Bolt, nut and locknut
- Screw 8x100 mm
- Screw 5x40 mm

Insulation

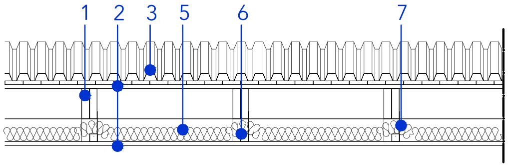
- Sheep wool 1000x l variable x100 mm

Sheet

- Corrugated sheet h 50 mm, distance 250 mm

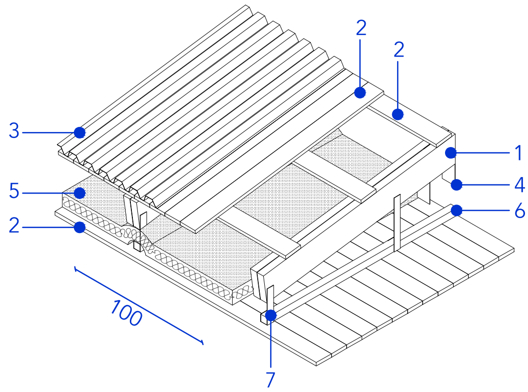
The length of the boards is uniform

CONSTRUCTIVE DETAIL



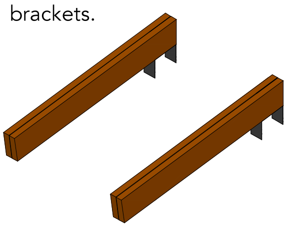
1- beam 200x50 mm
2- board 120x25 mm
3- corrugated sheet
4- bracket
5- wool insulation
6- wooden element 50x50 mm
7- steel hook

scale 1:50

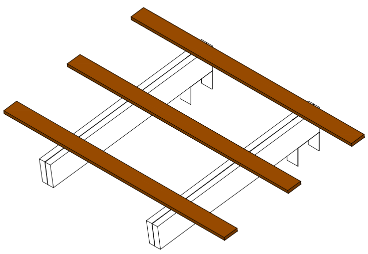


ASSEMBLY STEPS

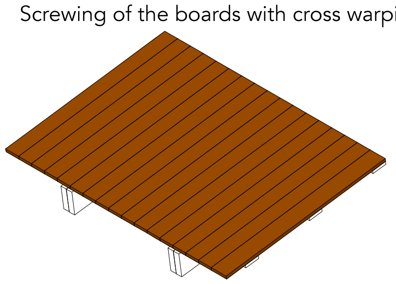
STEP_1
Positioning of the beams and connections through bolted brackets.



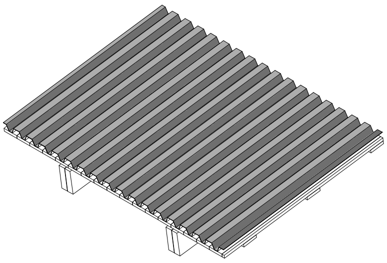
STEP_2
Screwing of the boards to the beams



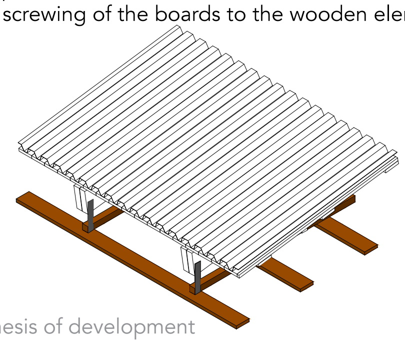
STEP_3
Screwing of the boards with cross warping



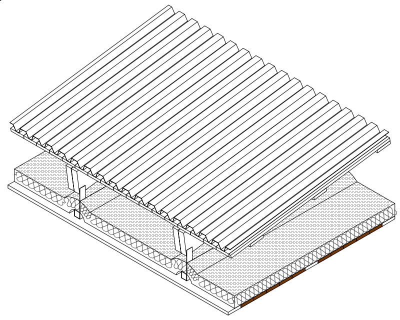
STEP_4
Bolting of the corrugated sheet to the boards



STEP_5
Screwing of the hooks to the beams, positioning of the wooden elements, screwing of the boards to the wooden elements



STEP_6
Positioning of insulation and completion of the assembly of the boards



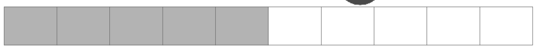
Technology assessment

COs_1

REVERSIBILITY

0 10

ASSEMBLY/DISASSEMBLY TIME



0 10

FLEXIBILITY

0 10

ASSEMBLY/DISASSEMBLY EASE

0 10

Environmental comfort

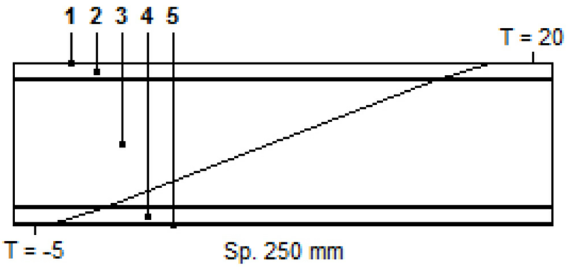
COs_1

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

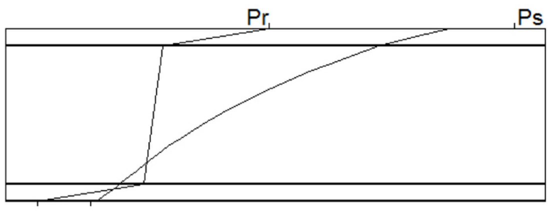
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Higher adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Slightly ventilated horizontal air layer	200	0.200	1.000	0.20	193.000	1008	1.000
4	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
5	Lower adduttance	0		25.000			0	0.040

RESISTANCE = 1.495 m²K/W	**AREIC HEAT CAPACITY** (sup) = 19.226 kJ/m²K	**TRASMITTANCE** = 0.669 W/m²K
THICKNESS = 250 mm	**AREIC HEAT CAPACITY** (inf) = 25.228 kJ/m²K	**SURFACE MASS** = 28 kg/m²
PERIODIC TRAMITTANCE = 1.44 W/m²K	**MITIGATION FACTOR** = 0.97	**DISPLACEMENT** = 1.49 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

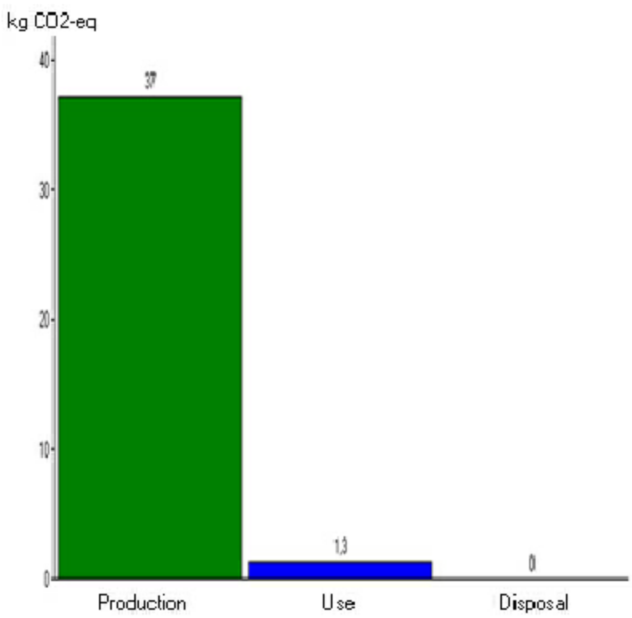


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

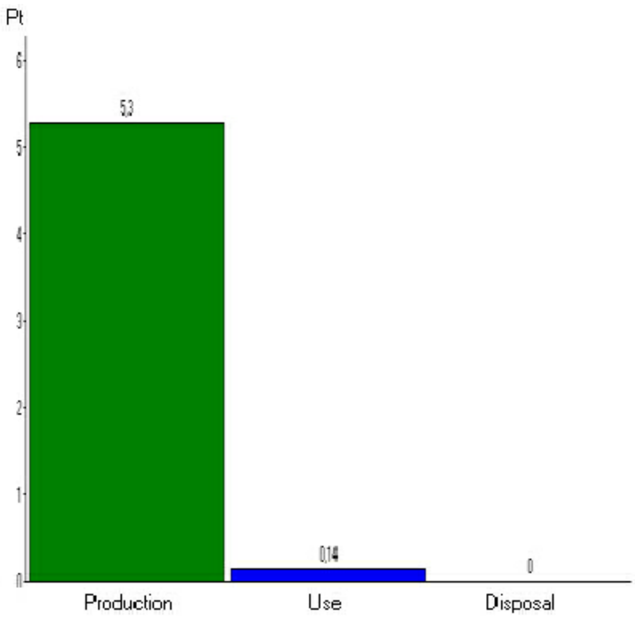
Life Cycle Assessment

COs_1

METHOD IPCC 2007- 38,3 KgCO2-eq



METHOD ReCiPe- 5,44 Pt



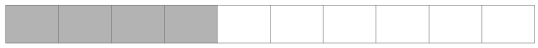
Technology assessment

COs_1a

REVERSIBILITY

ASSEMBLY/DISASSEMBLY TIME

FLEXIBILITY



ASSEMBLY/DISASSEMBLY EASE

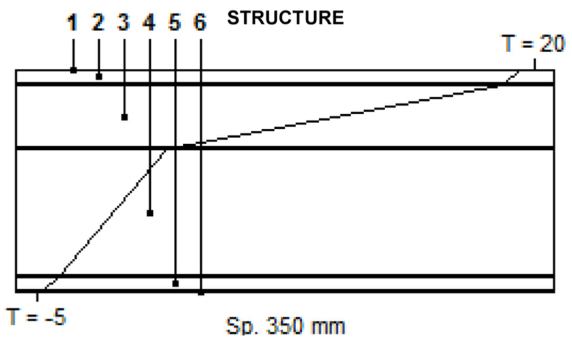
Environmental comfort

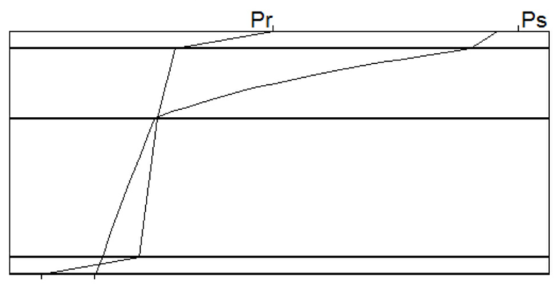
COs_1a

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Higher adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Sheep wool insulation	100	0.032	0.318	3.00	96.500	1300	3.145
4	Slightly ventilated horizontal air layer	200	0.200	1.000	0.20	193.000	1008	1.000
5	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
6	Lower adduttance	0		25.000			0	0.040

RESISTANCE = 4.639 m²K/W	**AREIC HEAT CAPACITY** (sup) = 23.031 kJ/m²K	**TRASMITTANCE** = 0.216 W/m²K
THICKNESS = 350 mm	**AREIC HEAT CAPACITY** (inf) = 24.596 kJ/m²K	**SURFACE MASS** = 31 kg/m²
PERIODIC TRAMITTANCE = 0.24 W/m²K	**MITIGATION FACTOR** = 0.93	**DISPLACEMENT** = 2.75 h



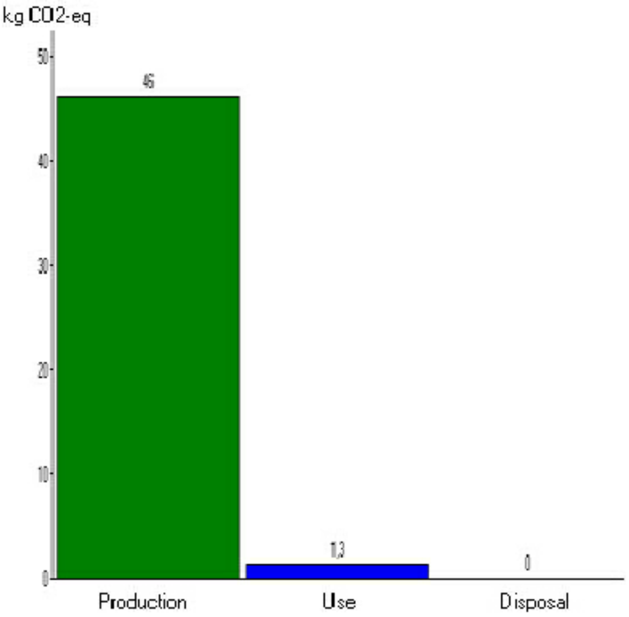


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

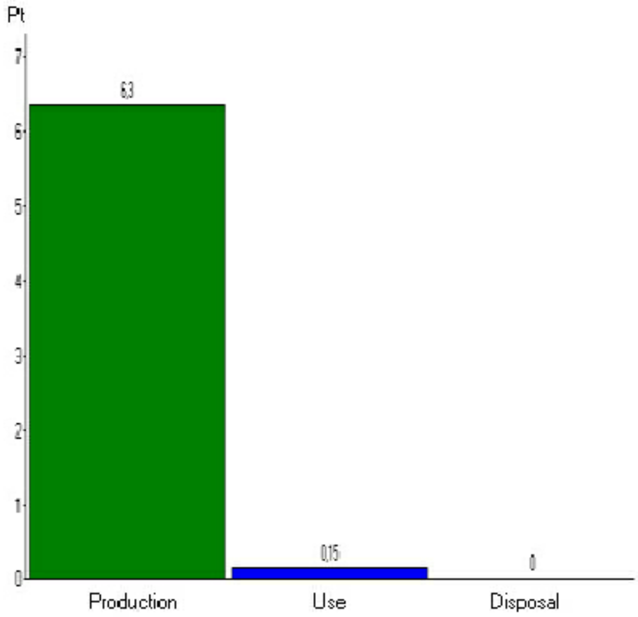
Life Cycle Assessment

COs_1a

METHOD IPCC 2007- 47,3 KgCO2-eq



METHOD ReCiPe- 6,45 Pt



Upper horizontal closure n_2

COs_2

COMPONENTS

Wooden elements

120x25 mm

300x40 mm

The length of the boards is uniform

Sheet

Corrugated sheet,
h 50 mm, distance 250 mm

Steel connections

Eyelet with screw

Omega connector
with screws

Tie rod diam.18

Bolt, nut and locknut

Multicom elements

Truss beam,
h 500mm, l ≤6000 mm

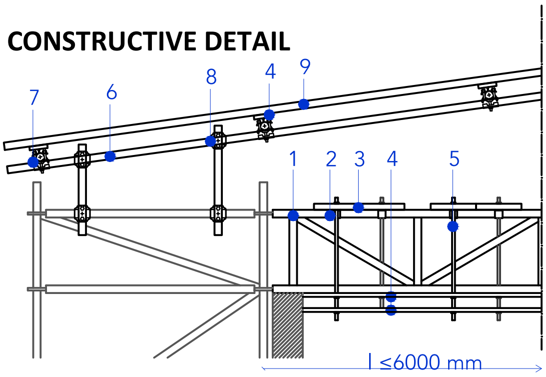
Tubular-joint system

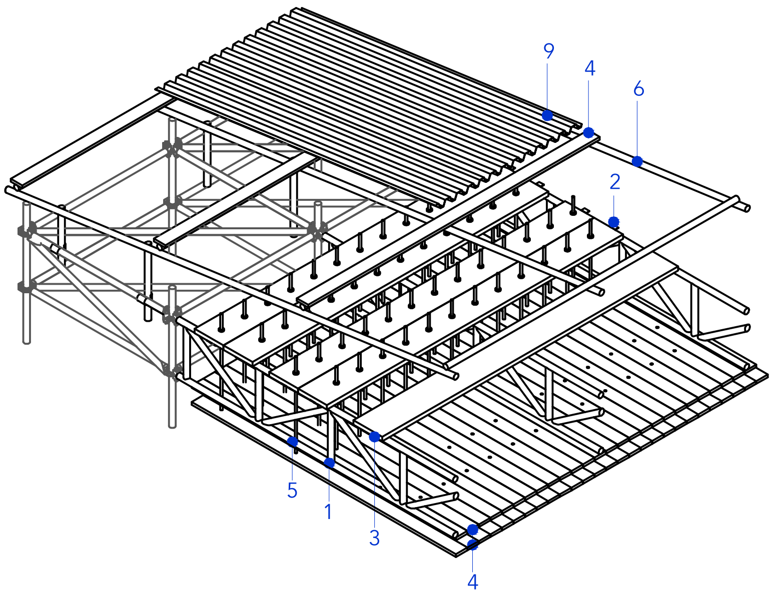
Tubular element,
l variable

Right angle
clamp

Swivel
clamp

CONSTRUCTIVE DETAIL





1- truss beam
2- omega connector
3- board 300x40 mm
4- board 120x25 mm
5- tie rod diam.18

6- tubular element
7- right angle clamp
8- swivel clamp
9- corrugated sheet

scale 1:50

variation a

COs_2a

COMPONENTS

Wooden elements

120x25 mm

300x40 mm

The length of the boards is uniform

Sheet

Corrugated sheet,
h 50 mm, distance 250 mm

Steel connections

Eyelet with screw

Omega connector
with screws

Tie rod diam.18

Bolt, nut and locknut

Multicom elements

Trave reticolare,
h 500mm, l ≤6000 mm

Tubular-joint system

Tubular element,
l variable

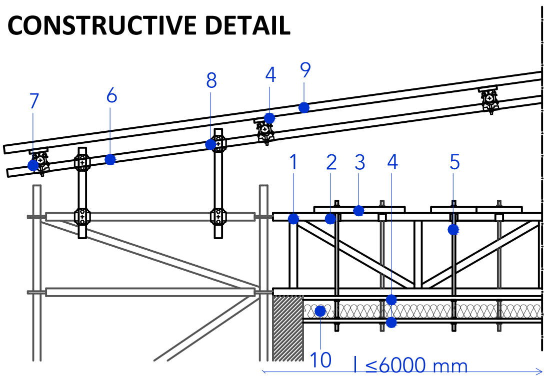
Right angle
clamp

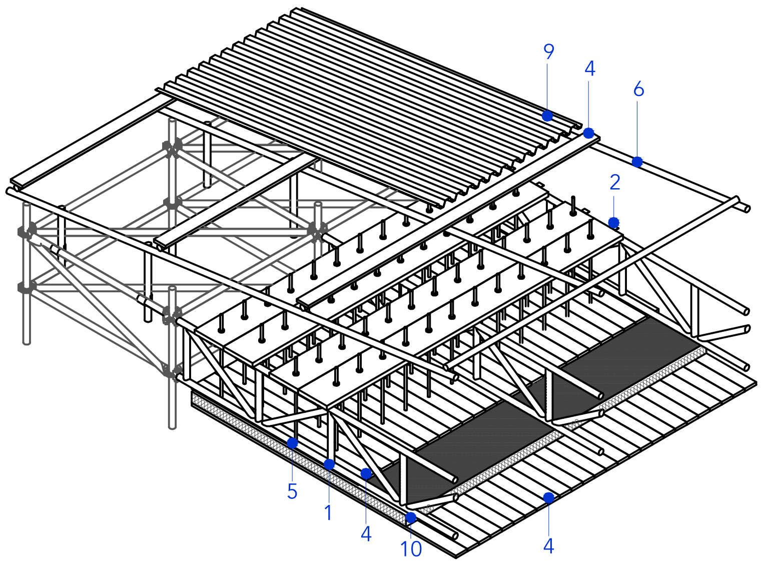
Swivel
clamp

Insulation

Wool insulation
800 x l variable x100 mm

CONSTRUCTIVE DETAIL





1- truss beam
2- omega connector
3- board 300x40 mm
4- board 120x25 mm
5- tie rod diam.18

6- tubular element
7- right angle clamp
8- swivel clamp
9- corrugated sheet
10- wool insulation

scale 1:50

variation b

COs_2b

COMPONENTS

Wooden elements

120x25 mm

300x40 mm

The length of the boards is uniform

Sheet

Corrugated sheet,
h 50 mm, distance 250 mm

Steel connections

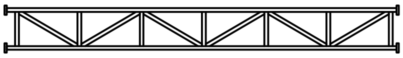
Eyelet with screw

Omega connector
with screw

Tie rod diam.18

Bolt, nut and locknut

Multicom elements

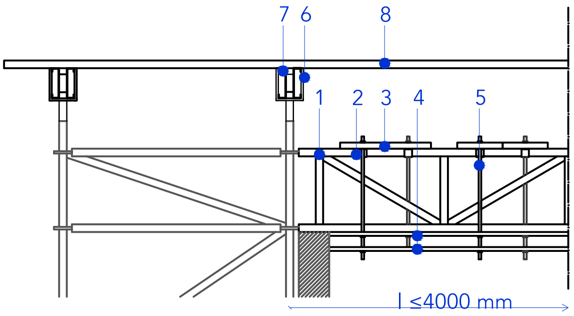


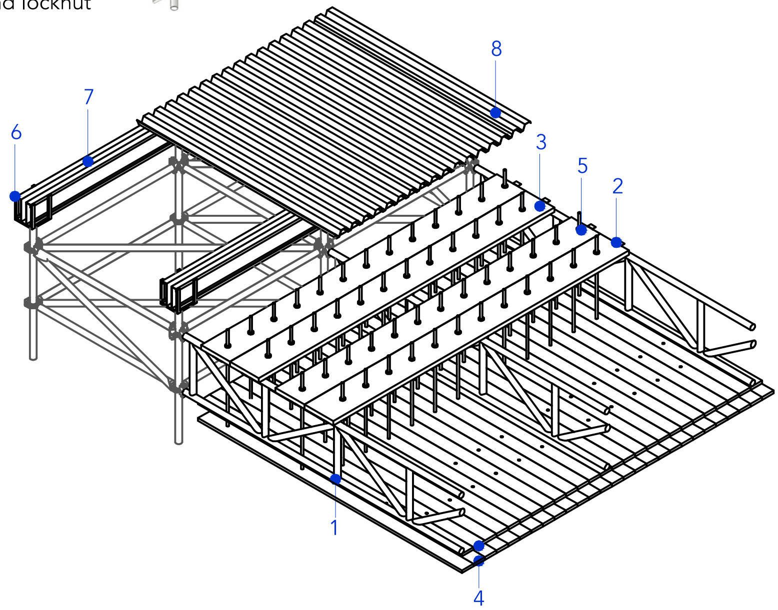
Truss beam,
h 500mm, l ≤6000 mm

Cross head

C profile, h 200 mm

CONSTRUCTIVE DETAIL





1- truss beam
2- omega connector
3- board 300x40 mm
4- board 120x25 mm

5- tie rod diam. 18
6- cross head
7- C profile
8- corrugated sheet

scale 1:50

variation c

COs_2c

COMPONENTS

Wooden elements

120x25 mm

300x40 mm

The length of the boards is uniform

Lamiera

Lamiera grecata,
h greca 50 mm, passo 250 mm

Steel connections

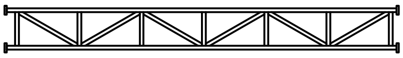
Eyelet with screw

Omega connector
with screws

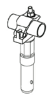
Tie rod diam.18

Bolt, nut and locknut

Multicom elements



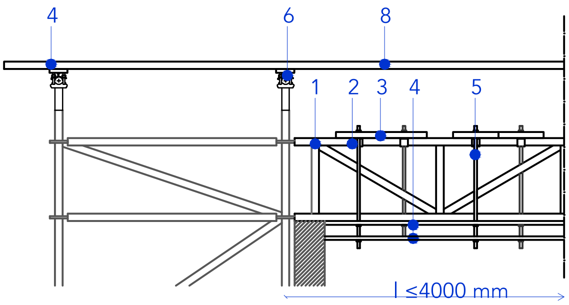
Truss beam,
h 500mm, l ≤6000 mm

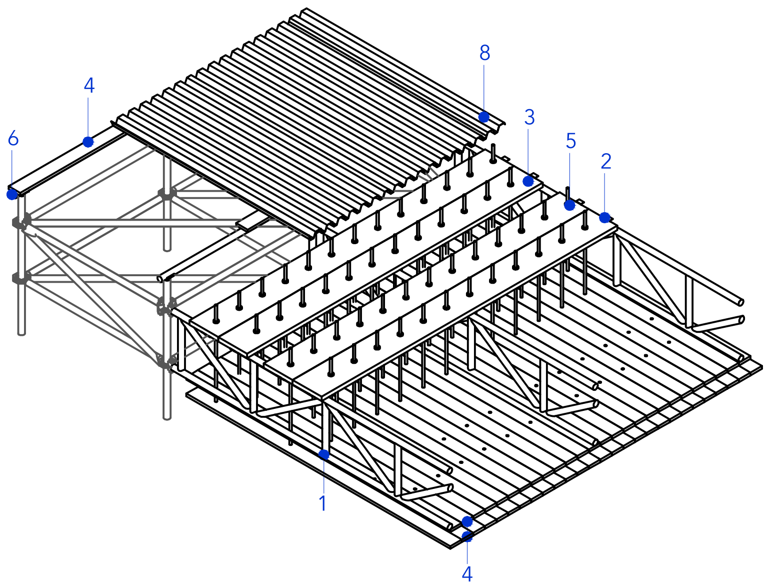


End joint

Tubular element,
l variable

CONSTRUCTIVE DETAIL





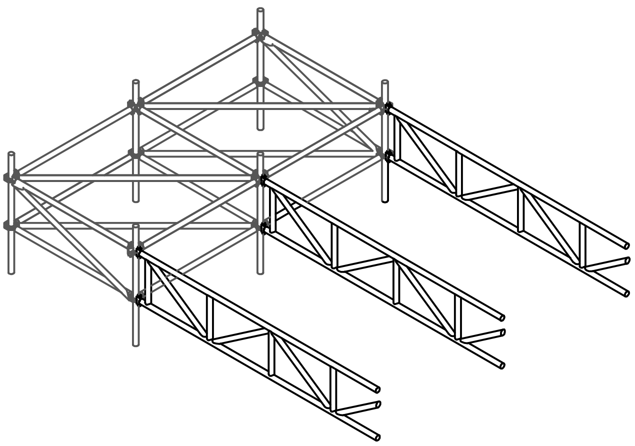
1- truss beam
2- omega connector
3- board 300x40 mm
4- board 120x25 mm

5- tie rod diam. 18
6- end joint
7- tubular element
8- corrugated sheet

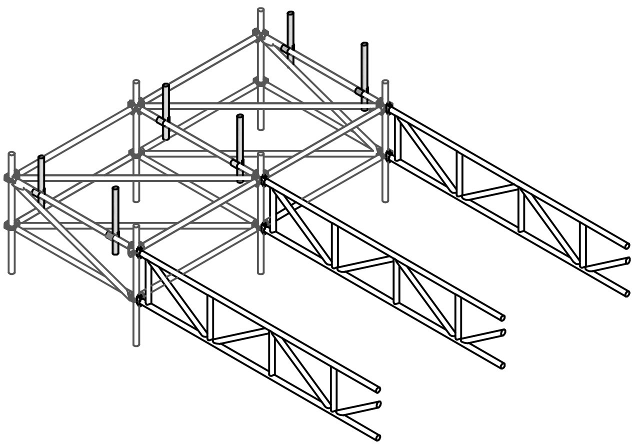
scale 1:50

ASSEMBLY STEPS

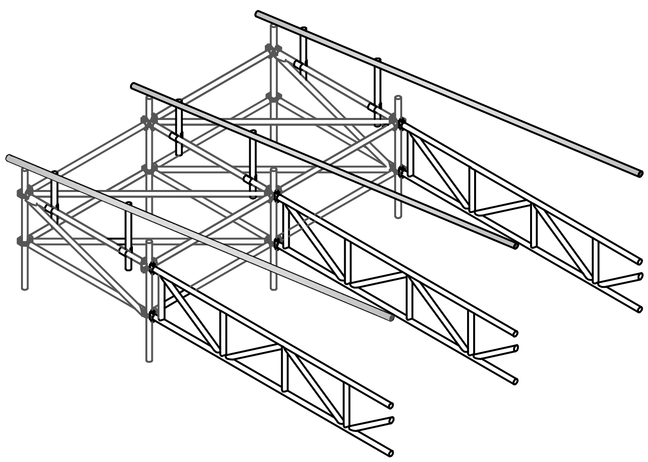
STEP_1
Assmebly of the truss beams



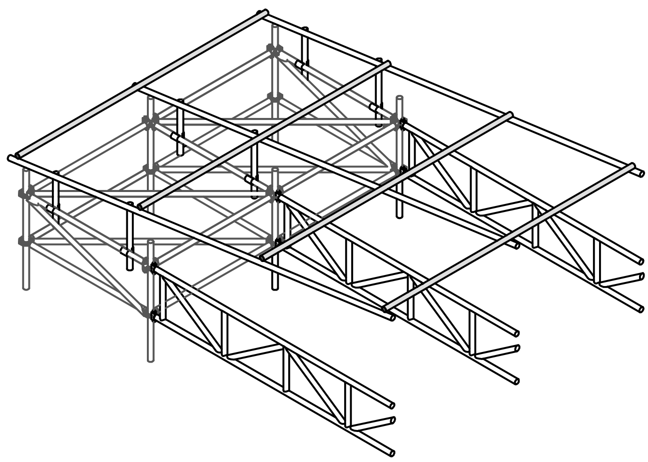
STEP_2
Assembly of the tubular elements with the multicom structure through right angle clamps



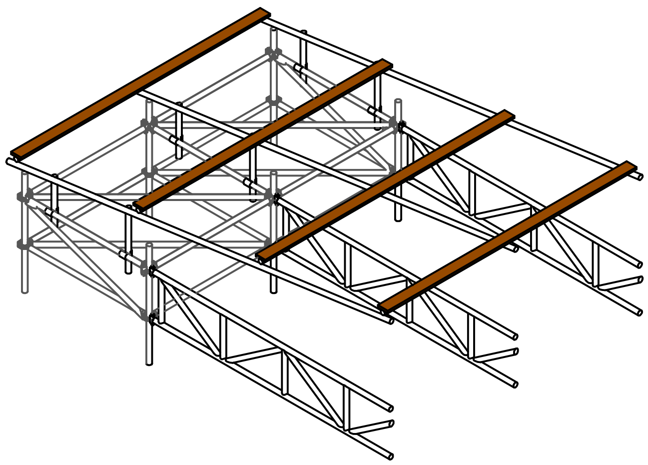
STEP_3
Assembly of tubular elements through swivel clamps



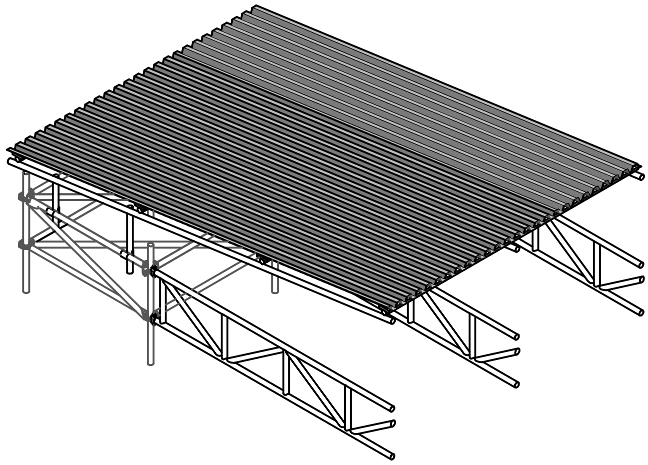
STEP_4
Assembly of tubular elements through right angle clamps with cross warping



STEP_5
Connection of the boards to the tubular elements through eyelets

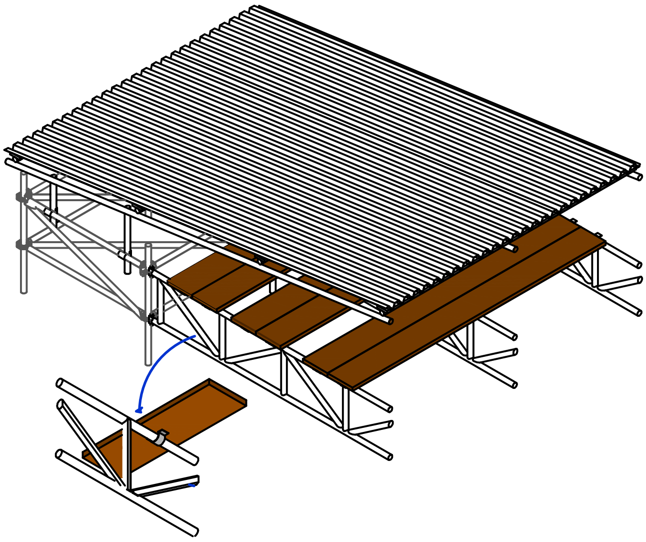


STEP_6
Assembly of the corrugated sheet through bolting to the wooden boards

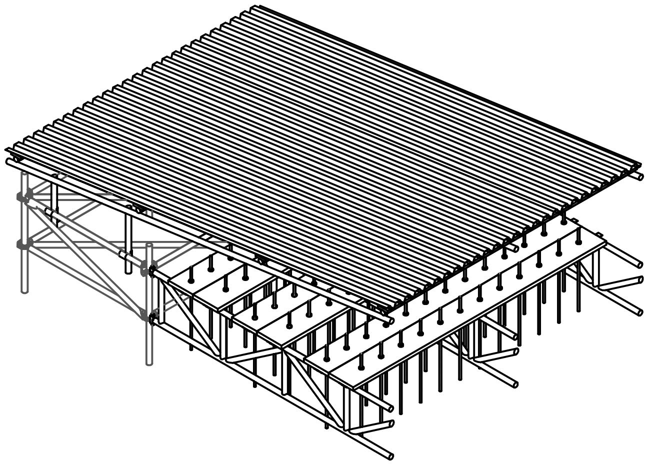


ASSEMBLY STEPS

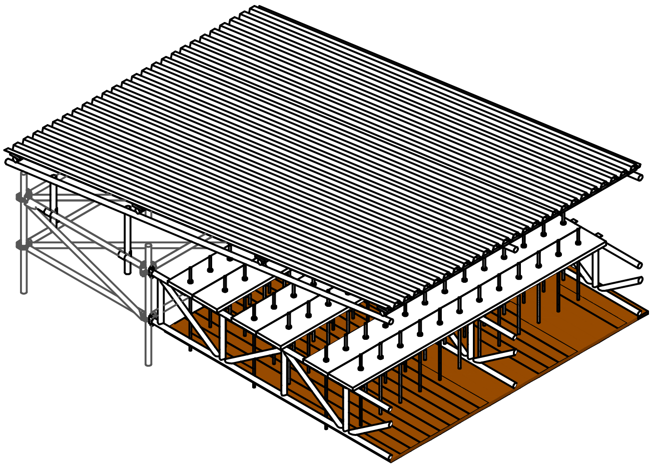
STEP_7
Connection of the wooden boards to the truss beams through omega connectors



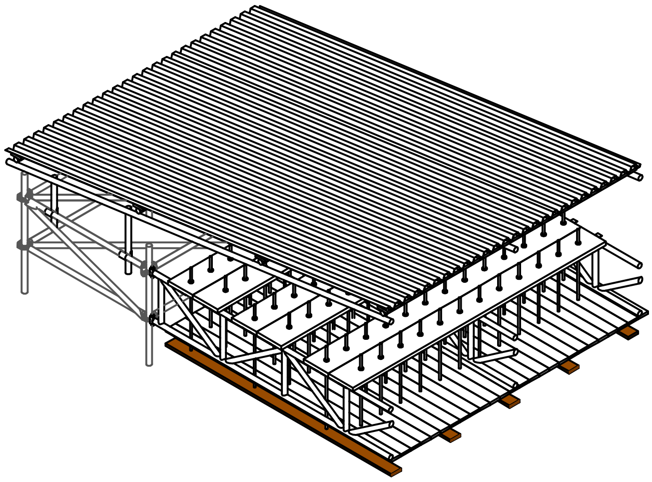
STEP_8
Positioning of the tie rods and blocking with nuts and locknuts



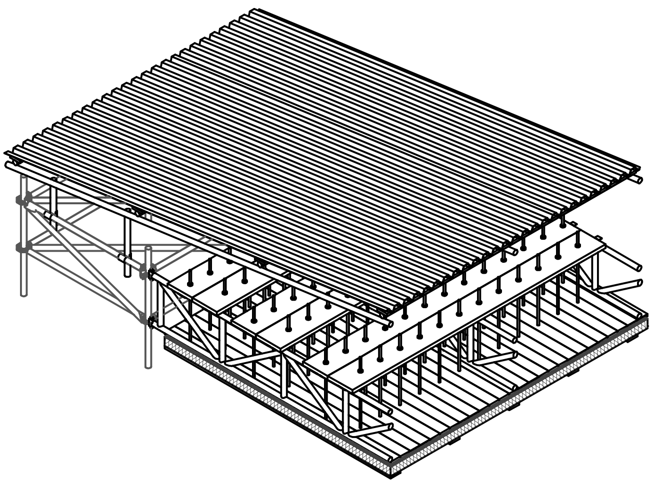
STEP_9
Connection of the wooden boards through the tie rods and blocking with nuts and locknuts



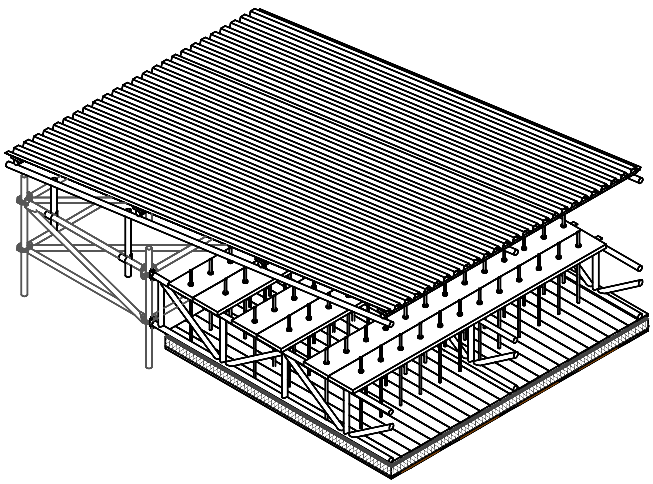
STEP_10
Connection of the wooden boards in alternate way through the tie rods and blocking with nuts and locknuts



STEP_11
Positioning of insulation



STEP_12
Final assembly of the wooden boards, connection through tie rods and blocking with nuts and locknuts



Technology assessment

COs_2

REVERSIBILITY

0 10

FLEXIBILITY

0 10

ASSEMBLY/DISASSEMBLY TIME

0 10

ASSEMBLY/DISASSEMBLY EASE

0 10

Environmental comfort

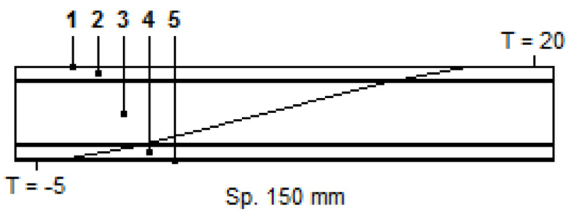
COs_2

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

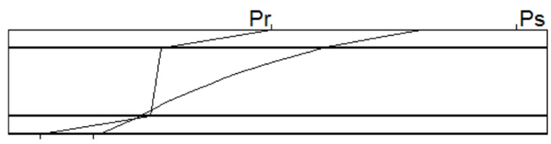
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Higher adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Slightly ventilated horizontal air layer	100	0.200	2.000	0.10	193.000	1008	0.500
4	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
5	Lower adduttance	0		25.000			0	0.040

RESISTANCE = 0.995 m²K/W	**AREIC HEAT CAPACITY** (sup) = 19.226 kJ/m²K	**TRASMITTANCE** = 1.005 W/m²K
THICKNESS = 150 mm	**AREIC HEAT CAPACITY** (inf) = 25.228 kJ/m²K	**SURFACE MASS** = 28 kg/m²
PERIODIC TRAMITTANCE = 1.44 W/m²K	**MITIGATION FACTOR** = 0.97	**DISPLACEMENT** = 1.49 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

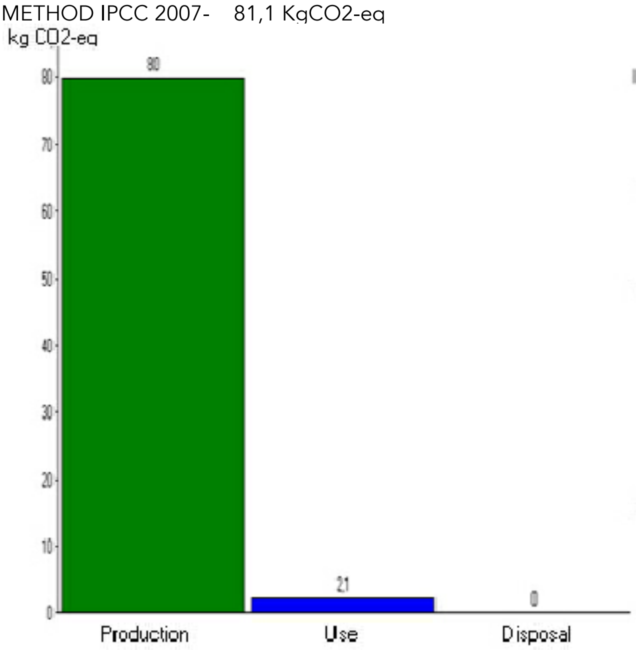


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

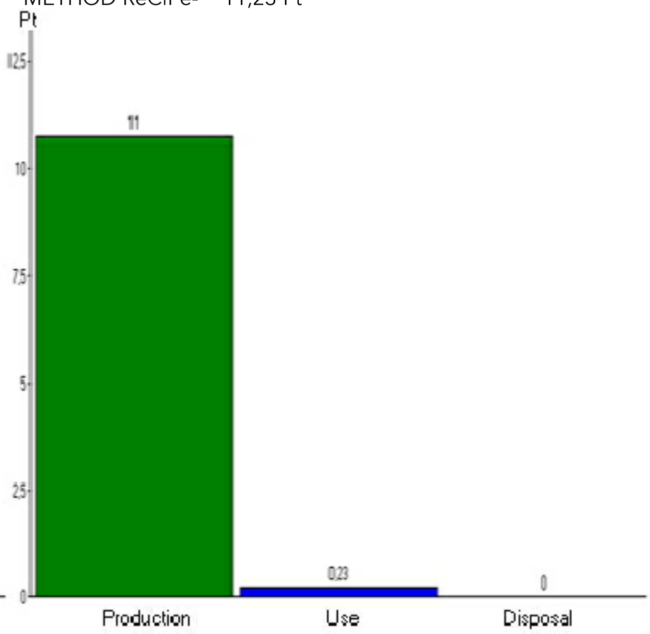
Life Cycle Assessment

COs_2

METHOD IPCC 2007- 81,1 KgCO2-eq



METHOD ReCiPe- 11,23 Pt



Technology assessment

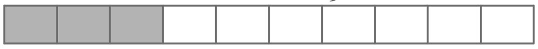
COs_2a

REVERSIBILITY

ASSEMBLY/DISASSEMBLY TIME

FLEXIBILITY

ASSEMBLY/DISASSEMBLY EASE



Environmental comfort

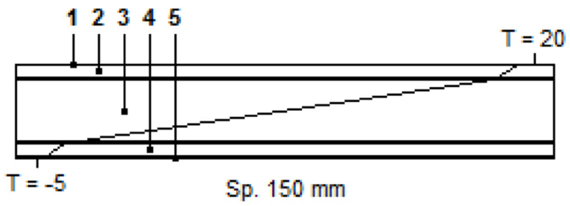
COs_2a

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

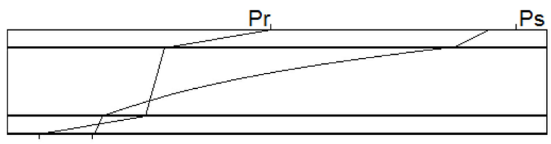
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Higher adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Sheep wool insulation	100	0.032	0.318	3.00	96.500	1300	3.145
4	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
5	Lower adduttance	0		25.000			0	0.040

RESISTANCE= 3.639 m²K/W	**AREIC HEAT CAPACITY**(sup) = 22.941 kJ/m²K	**TRASMITTANCE**= 0.275 W/m²K
THICKNESS= 150 mm	**AREIC HEAT CAPACITY** (inf) = 24.720 kJ/m²K	**SURFACE MASS**= 31 kg/m²
PERIODIC TRAMITTANCE= 0.26 W/m²K	**MITIGATION FACTOR**= 0.93	**DISPLACEMENT**= 2.69 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

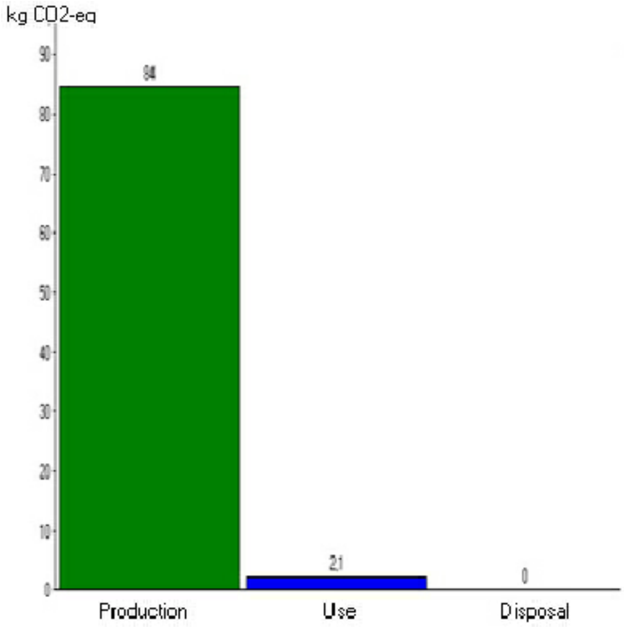


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

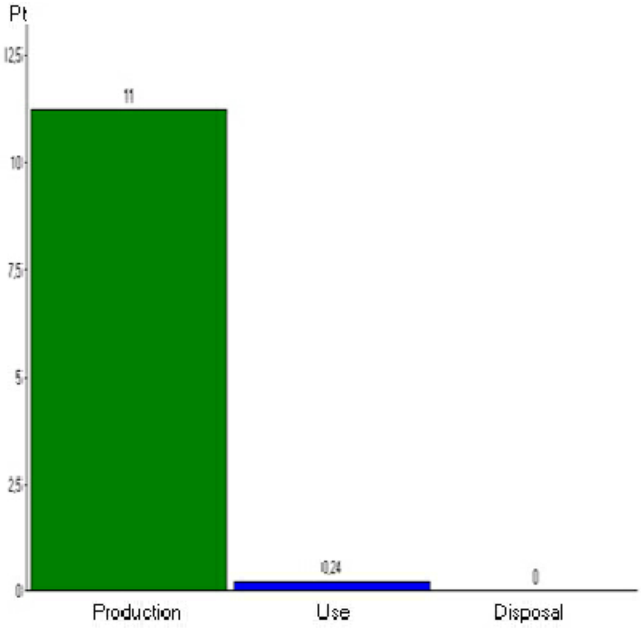
Life Cycle Assessment

COs_2a

METHOD IPCC 2007- 86,1 KgCO2-eq



METHOD ReCiPe- 11,24 Pt



Technology assessment

COs_2b

REVERSIBILITY

0 10

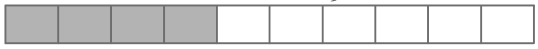
ASSEMBLY/DISASSEMBLY TIME

0 10

FLEXIBILITY

0 10

ASSEMBLY/DISASSEMBLY EASE



0 10

Environmental comfort

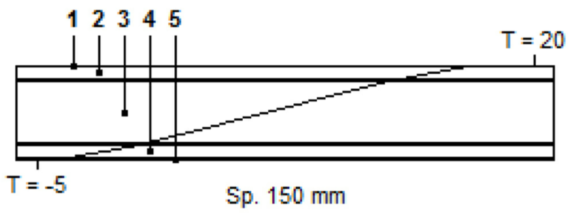
COs_2b

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

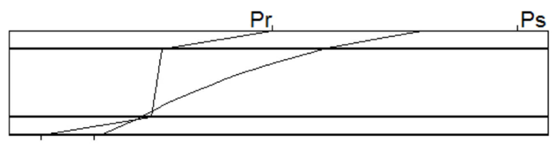
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Higher addittance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Slightly ventilated horizontal air layer	100	0.200	2.000	0.10	193.000	1008	0.500
4	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
5	Lower addittance	0		25.000			0	0.040

RESISTANCE = 0.995 m²K/W	**AREIC HEAT CAPACITY** (sup) = 19.226 kJ/m²K	**TRASMITTANCE** = 1.005 W/m²K
THICKNESS = 150 mm	**AREIC HEAT CAPACITY** (inf) = 25.228 kJ/m²K	**SURFACE MASS** = 28 kg/m²
PERIODIC TRAMITTANCE = 1.44 W/m²K	**MITIGATION FACTOR** = 0.97	**DISPLACEMENT** = 1.49 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

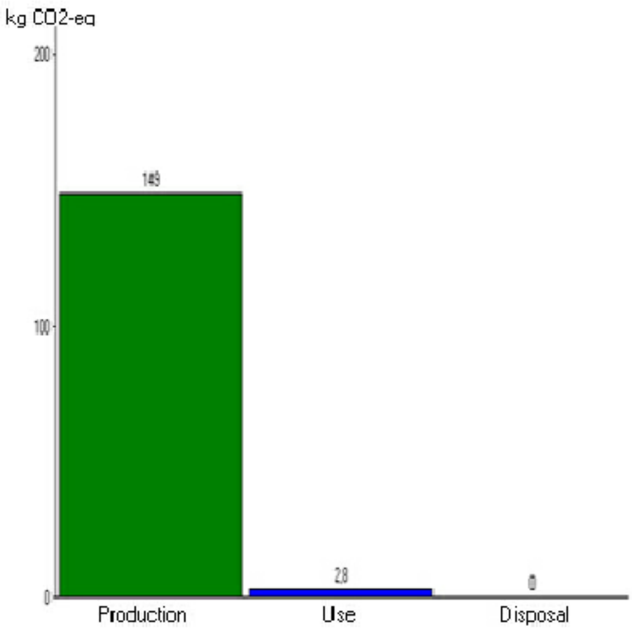


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

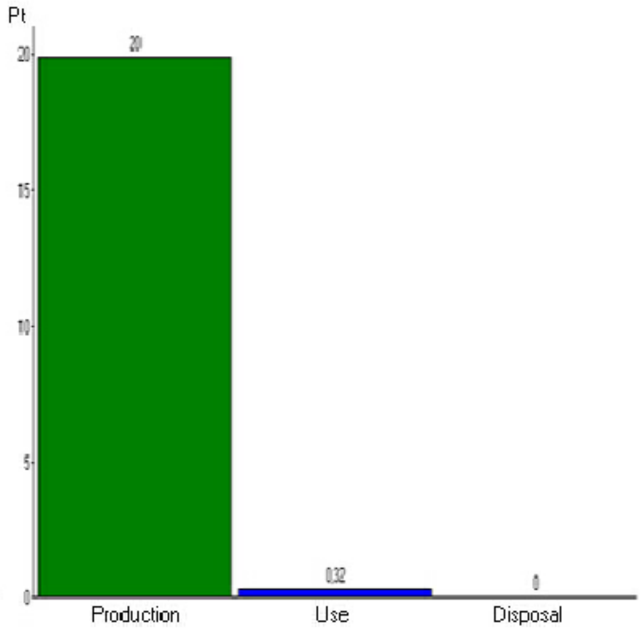
Life Cycle Assessment

COs_2b

METHOD IPCC 2007- 151,8 KgCO2-eq



METHOD ReCiPe- 19,32 Pt



Technology assessment

COs_2c

REVERSIBILITY

0 10

FLEXIBILITY

0 10

ASSEMBLY/DISASSEMBLY TIME

0 10

ASSEMBLY/DISASSEMBLY EASE

0 10

Environmental comfort

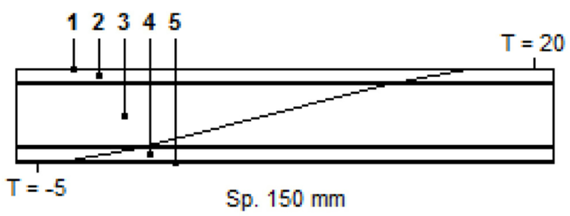
COs_2c

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

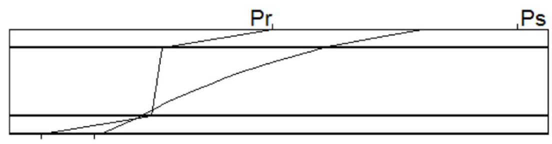
N.	Layer	s [mm]	lambda [W/mK]	C [W/m^2K]	M.S. [kg/m^2]	$P<50*10^{12}$ [kg/msPa]	C.S. [J/kgK]	R [m^2K/W]
1	Higher adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Slightly ventilated horizontal air layer	100	0.200	2.000	0.10	193.000	1008	0.500
4	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
5	Lower adduttance	0		25.000			0	0.040

RESISTANCE = 0.995 m^2K/W	**AREIC HEAT CAPACITY** (sup) = 19.226 kJ/m^2K	**TRASMITTANCE** = 1.005 W/m^2K
THICKNESS = 150 mm	**AREIC HEAT CAPACITY** (inf) = 25.228 kJ/m^2K	**SURFACE MASS** = 28 kg/m^2
PERIODIC TRAMITTANCE = 1.44 W/m^2K	**MITIGATION FACTOR** = 0.97	**DISPLACEMENT** = 1.49 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

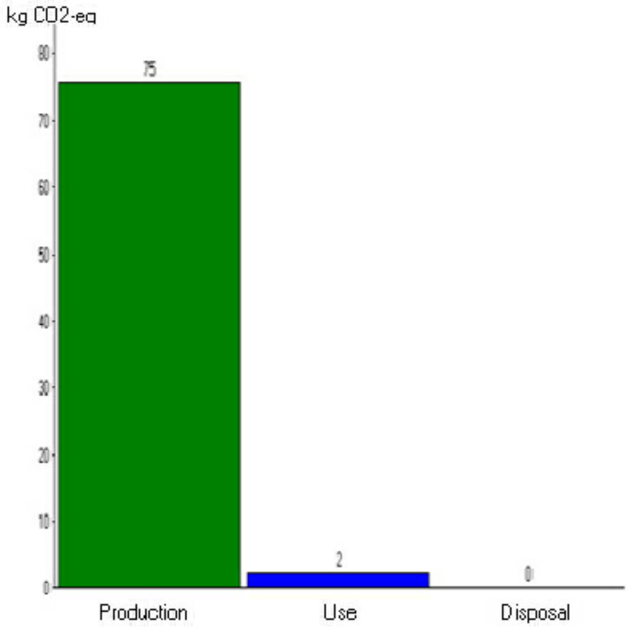


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

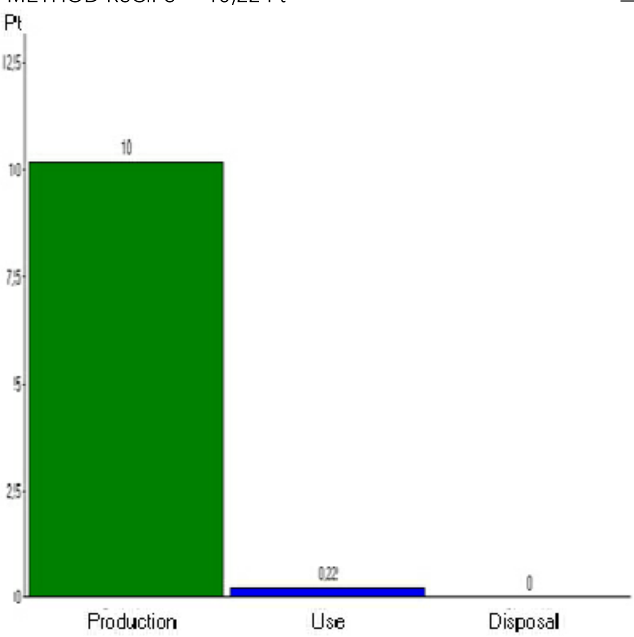
Life Cycle Assessment

COs_2c

METHOD IPCC 2007- 77 KgCO2-eq



METHOD ReCiPe- 10,22 Pt



Upper horizontal closure n_3

COs_3

COMPONENTS

Wooden elements

50x50 mm

120x25 mm

The length of the boards is uniform

Sheet

Corrugated sheet,
h 50 mm, distance 250 mm

Steel connections

Eyelet with screw

Screw 5x40 mm

Tie rod diam.18

Anchor plate

Bolt, nut and locknut

Tubular-joint system

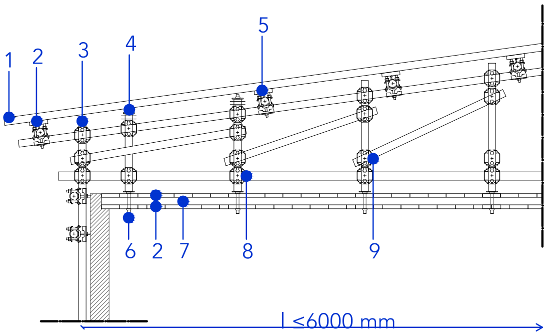
Tubular element,
l variable

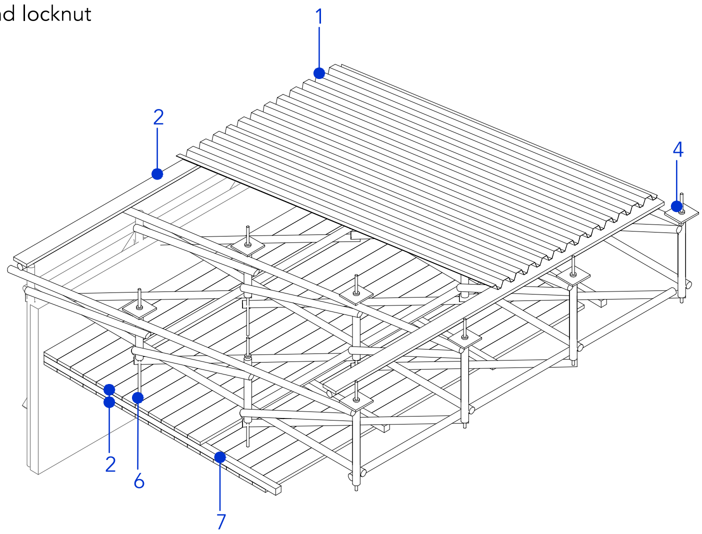
Anchor pin

Right angle
clamp

Swivel
clamp

CONSTRUCTIVE DETAIL





1- corrugated sheet
2- board 120x25 mm
3- tubular element
4- anchor plate
5- eyelet with screw

6- tie rod diam. 18
7- wooden element 50x50 mm
8- right angle clamp
9- swivel clamp

scale 1:50

variation a

COs_3a

COMPONENTS

Wooden elements

50x50 mm

120x25 mm

The length of the boards is uniform

Sheet

Corrugated sheet,
h 50 mm, distance 250 mm

Steel connections

Eyelet with screw

Screw 5x40 mm

Tie rod diam.18

Anchor plate

Bolt, nut and locknut

Tubular-joint system

Tubular element,
l variable

Anchor pin

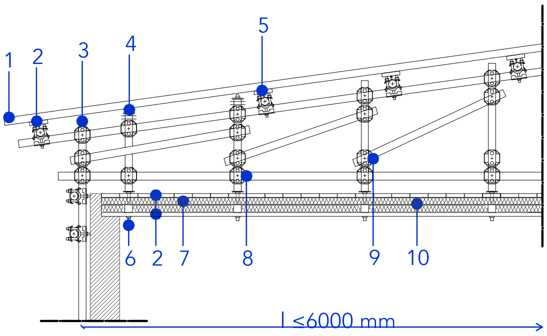
Right angle
clamp

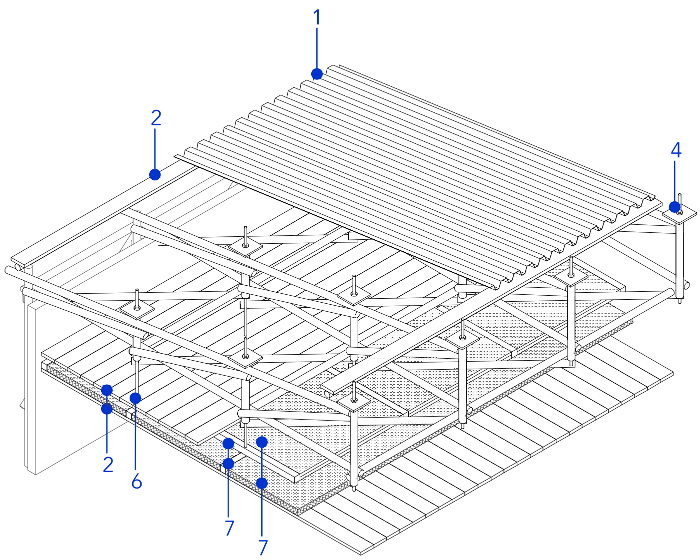
Swivel clamp

Insulation

Sheep wool
1000 x l variable x 50 mm

CONSTRUCTIVE DETAIL





1- corrugated sheet
2- board 120x25 mm
3- tubular element
4- anchor plate
5- eyelet with screw

6- tie rod diam. 18
7- wooden element 50x50 mm
8- right angle clamp
9- swivel clamp
10- wool insulation

scale 1:50

variation b

COs_3b

COMPONENTS

Wooden elements
- 50x50 mm
- 120x25 mm
- 60x25 mm

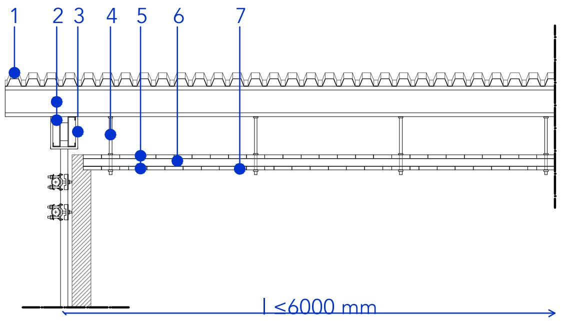
The length of the boards is uniform

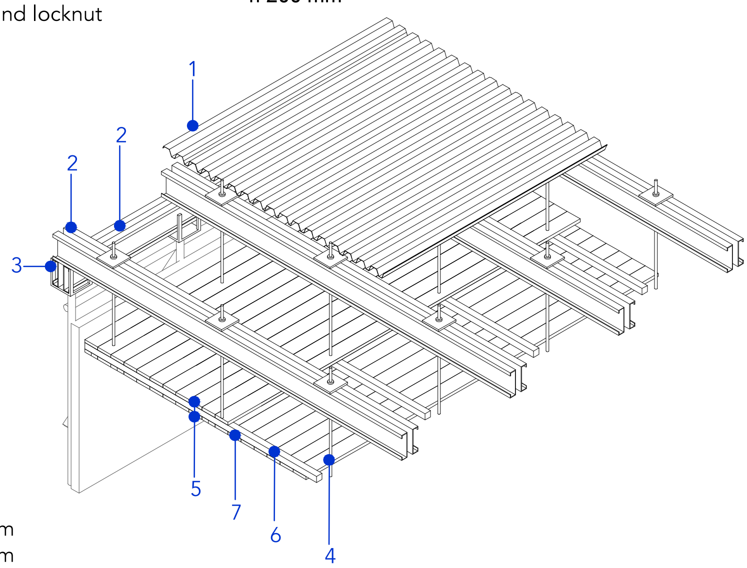
Steel connections
- Screw 5x40 mm
- Tie rod diam.18
- Anchor plate
- Bolt, nut and locknut

Multicom elements
- Cross head
- C profile, h 200 mm

Sheet
- Corrugated sheet, h 50 mm, distance 250 mm

CONSTRUCTIVE DETAIL





1- corrugated sheet
2- C profile
3- cross head
4- tie rod diam.18
5- board 120x25 mm
6- wooden element 50x50 mm
7- wooden element 60x25 mm

scale 1:50

variation c

COs_3c

COMPONENTS

Wooden elements
- 50x50 mm
- 60x25 mm
- 120x25 mm
- 200x50 mm

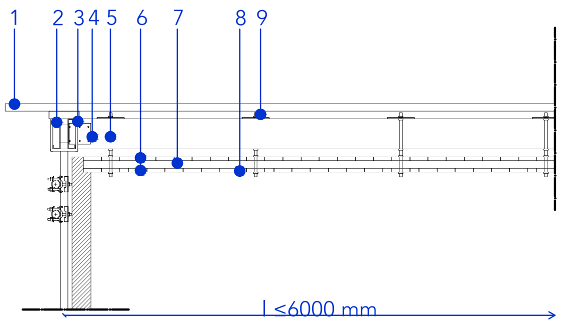
The length of the boards is uniform

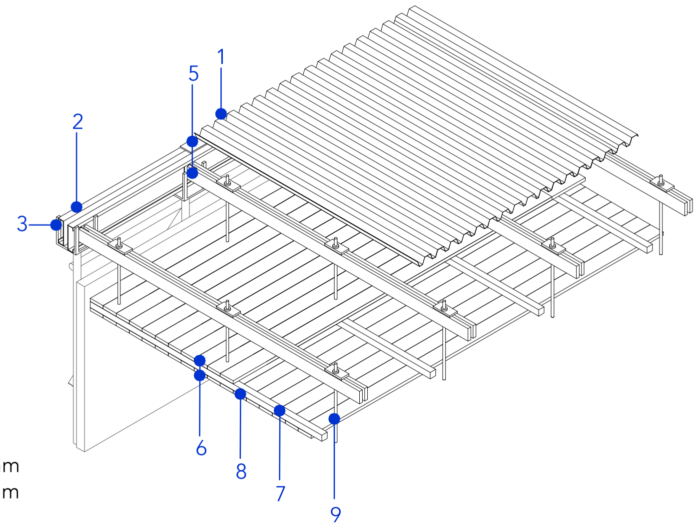
Steel connections
- Screw 5x40 mm
- Tie rod diam.18
- Anchor plate
- Bolt, nut and locknut
- Bracket 150x150 mm

Multicom elements
- Cross head
- C profile, h 200 mm

Sheet
- Corrugated sheet, h 50 mm, distance 250 mm

CONSTRUCTIVE DETAIL



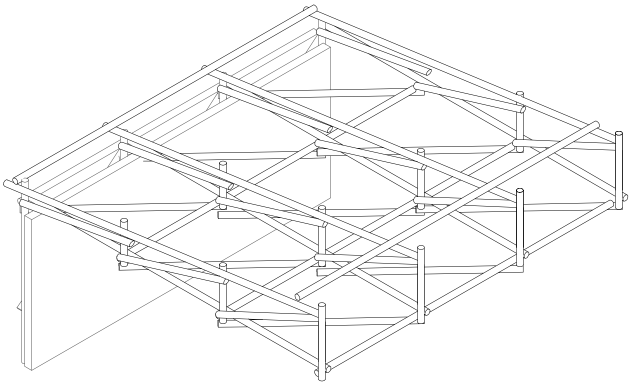


1- corrugated sheet
2- C profile
3- cross head
4- bracket
5- beam 200x50 mm
6- board 120x25 mm
7- wooden element 50x50 mm
8- wooden element 60x25 mm
9- tie rod diam.18 mm

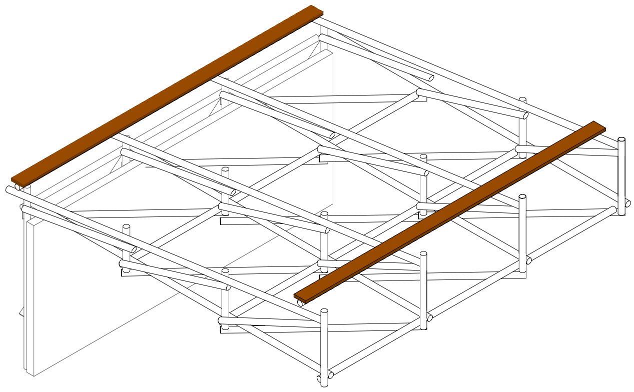
scale 1:50

ASSEMBLY STEPS

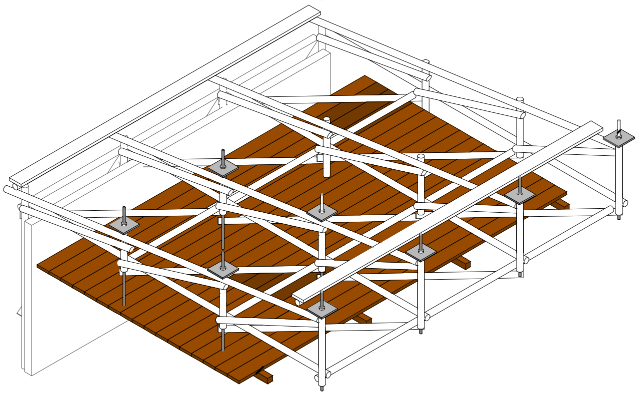
STEP_1
Assembly of tubular-joint structure



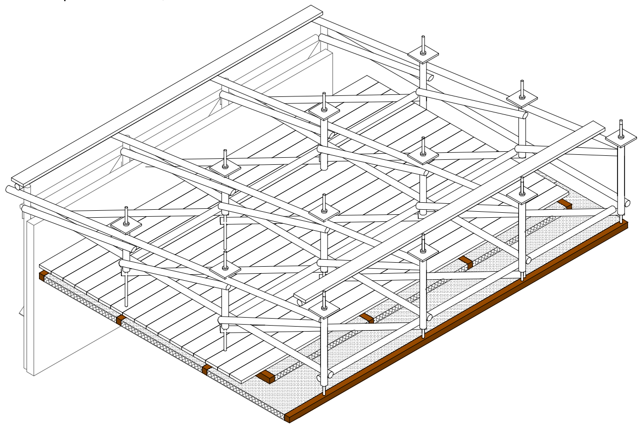
STEP_2
Positioning of the wooden boards and connections through eyelets with screws



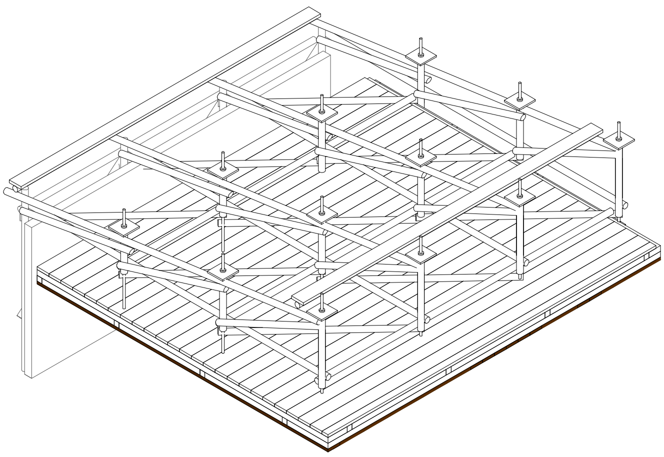
STEP_3
Positioning of the tie rods in the vertical tubular elements and blocking with anchor plates and bolts, positioning of wooden elements, screwing of the boards



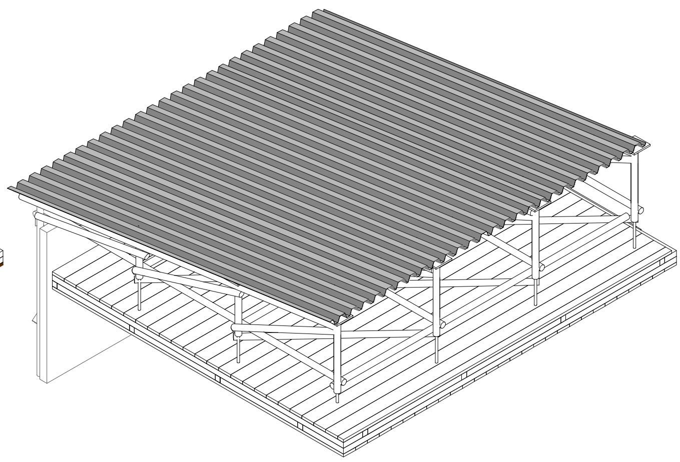
STEP_4
Screwing of the wooden elements to the overlying wooden elements with cross warping, positioning of insulation



STEP_5
Screwing of the boards to the wooden elements with cross warping



STEP_6
Assembly of corrugated sheet



Technology assessment

COs_3

REVERSIBILITY

ASSEMBLY/DISASSEMBLY TIME

FLEXIBILITY

ASSEMBLY/DISASSEMBLY EASE

Environmental comfort

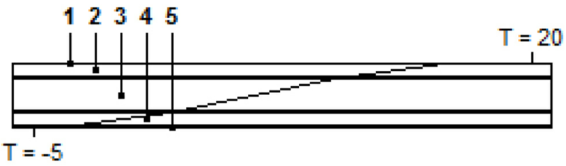
COs_3

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Higher adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Slightly ventilated horizontal air layer	50	0.200	4.000	0.05	193.000	1008	0.250
4	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
5	Lower adduttance	0		25.000			0	0.040

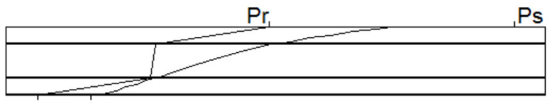
RESISTANCE = 0.745 m²K/W	**AREIC HEAT CAPACITY** (sup) = 19.226 kJ/m²K	**TRASMITTANCE** = 1.343 W/m²K
THICKNESS = 100 mm	**AREIC HEAT CAPACITY** (inf) = 25.228 kJ/m²K	**SURFACE MASS** = 28 kg/m²
PERIODIC TRAMITTANCE = 1.44 W/m²K	**MITIGATION FACTOR** = 0.97	**DISPLACEMENT** = 1.49 h

STRUCTURE



Sp. 100 mm

DIAGRAMS OF THE PRESSURES

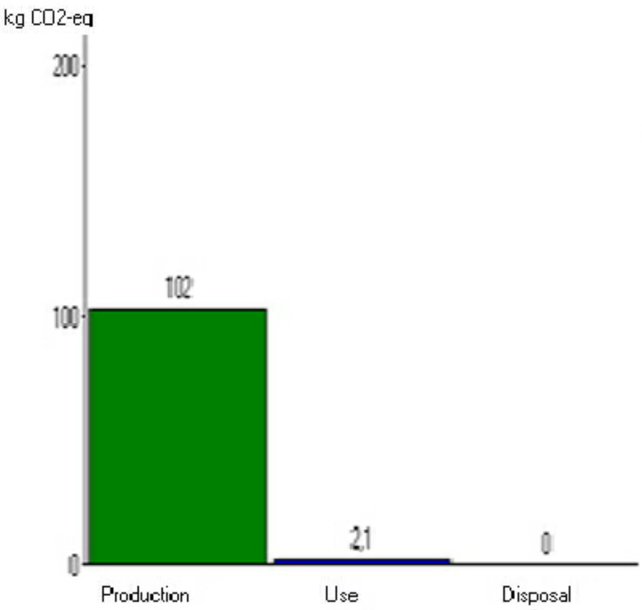


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

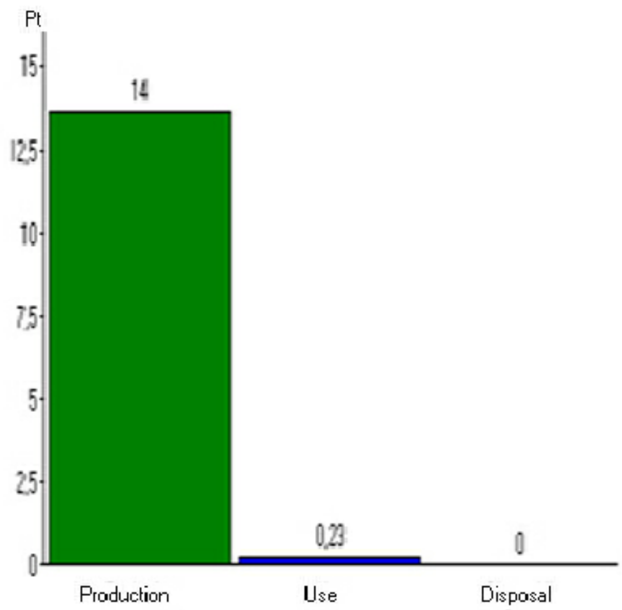
Life Cycle Assessment

COs_3

METHOD IPCC 2007- 104,1 KgCO2-eq

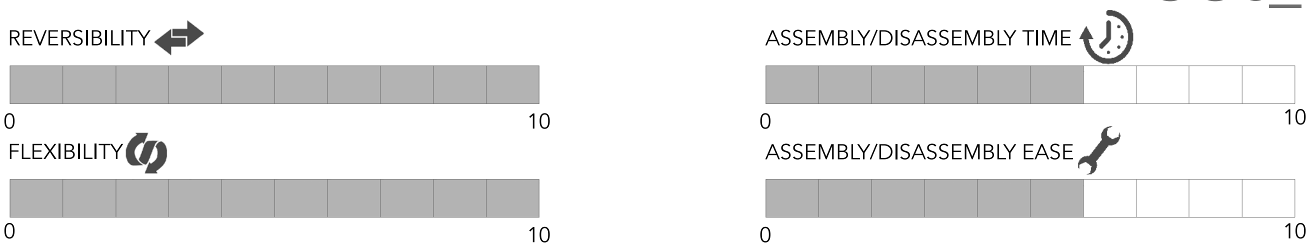


METHOD ReCiPe- 14,23 Pt



Technology assessment

COs_3a



Environmental comfort

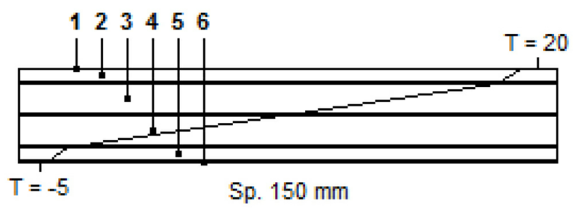
COs_3a

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

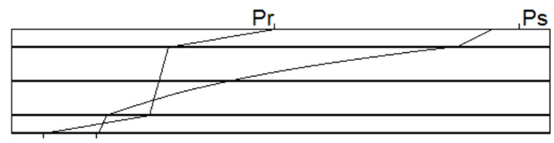
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Higher adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Sheep wool insulation	50	0.032	0.636	1.50	96.500	1300	1.572
4	Sheep wool insulation	50	0.032	0.636	1.50	96.500	1300	1.572
5	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
6	Lower adduttance	0		25.000			0	0.040

RESISTANCE = 3.639 m²K/W	**AREIC HEAT CAPACITY** (sup) = 22.941 kJ/m²K	**TRASMITTANCE** = 0.275 W/m²K
THICKNESS = 150 mm	**AREIC HEAT CAPACITY** (inf) = 24.720 kJ/m²K	**SURFACE MASS** = 31 kg/m²
PERIODIC TRAMITTANCE = 0.26 W/m²K	**MITIGATION FACTOR** = 0.93	**DISPLACEMENT** = 2.69 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

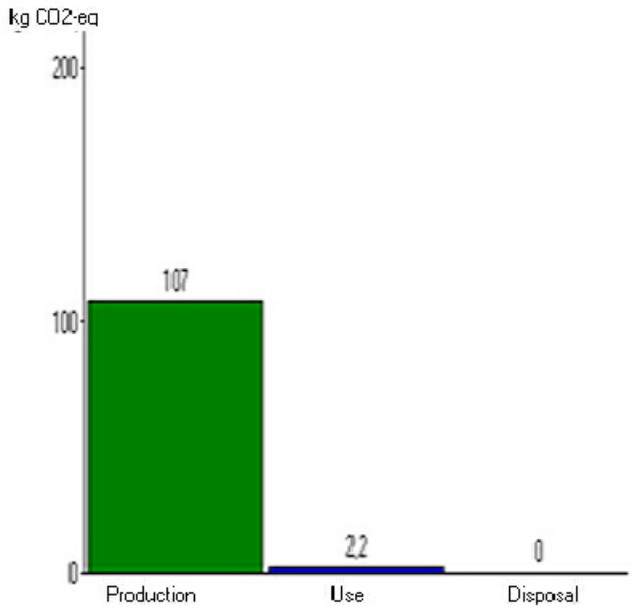


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

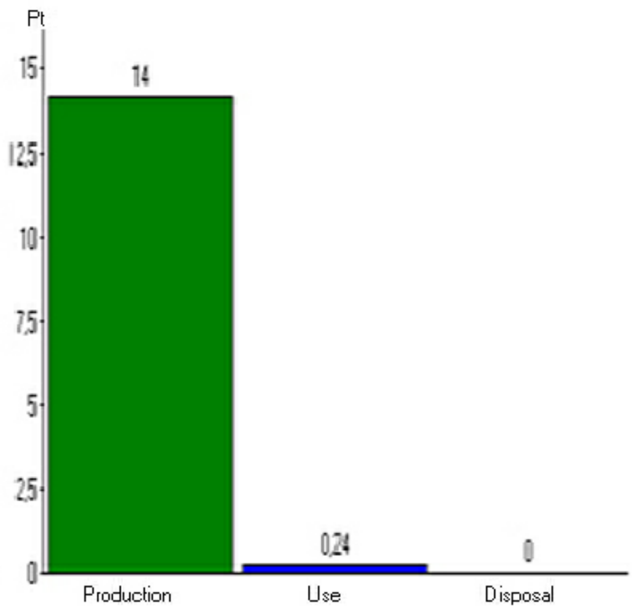
Life Cycle Assessment

COs_3a

METHOD IPCC 2007- 109,2 KgCO2-eq



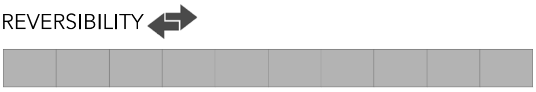
METHOD ReCiPe- 14,24 Pt



Technology assessment

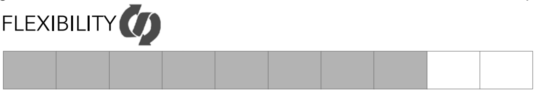
COs_3b

REVERSIBILITY



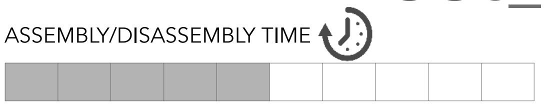
0 10

FLEXIBILITY



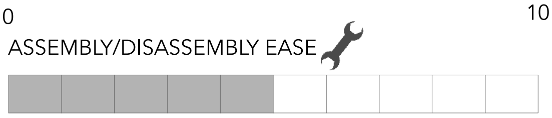
0 10

ASSEMBLY/DISASSEMBLY TIME



0 10

ASSEMBLY/DISASSEMBLY EASE



0 10

Environmental comfort

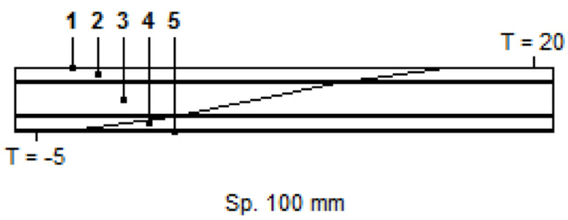
COs_3b

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

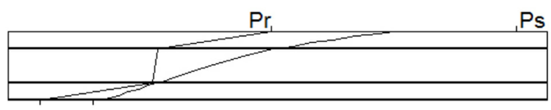
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Higher adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Slightly ventilated horizontal air layer	50	0.200	4.000	0.05	193.000	1008	0.250
4	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
5	Lower adduttance	0		25.000			0	0.040

RESISTANCE = 0.745 m²K/W	**AREIC HEAT CAPACITY** (sup) = 19.226 kJ/m²K	**TRASMITTANCE** = 1.343 W/m²K
THICKNESS = 100 mm	**AREIC HEAT CAPACITY** (inf) = 25.228 kJ/m²K	**SURFACE MASS** = 28 kg/m²
PERIODIC TRAMITTANCE = 1.44 W/m²K	**MITIGATION FACTOR** = 0.97	**DISPLACEMENT** = 1.49 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

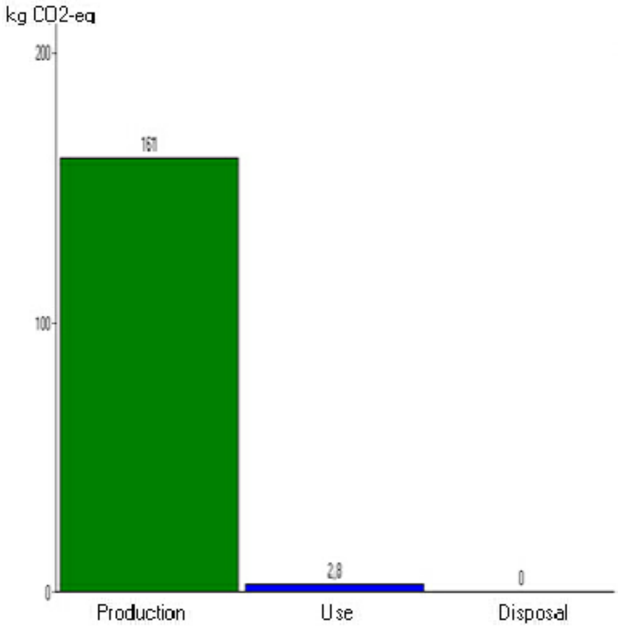


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

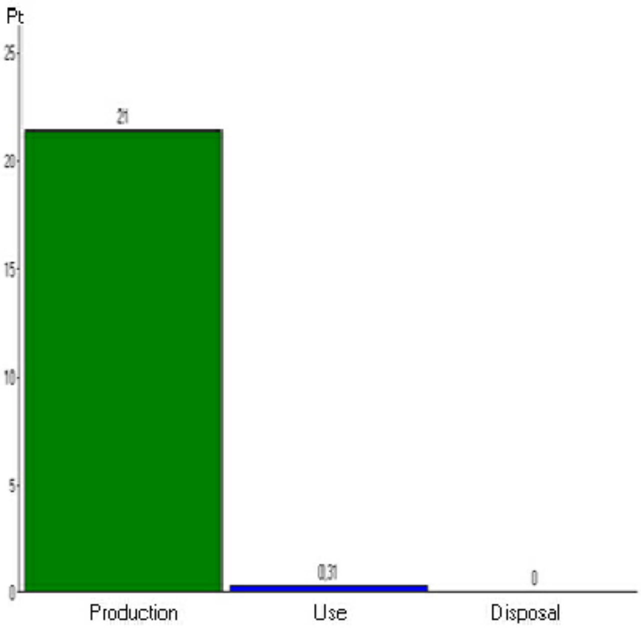
Life Cycle Assessment

COs_3b

METHOD IPCC 2007- 163,8 KgCO2-eq

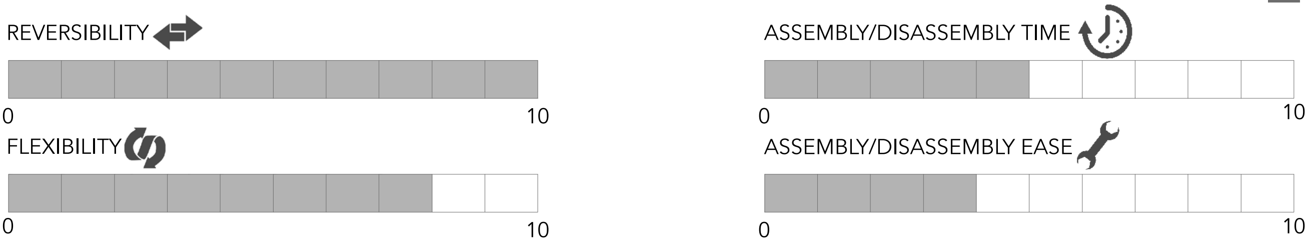


METHOD ReCiPe- 21,31 Pt



Technology assessment

COs_3c



Environmental comfort

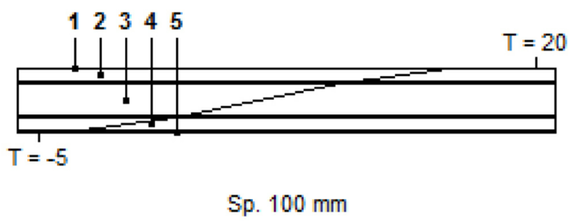
COs_3c

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

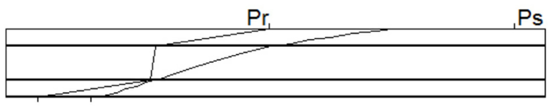
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Higher adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Slightly ventilated horizontal air layer	50	0.200	4.000	0.05	193.000	1008	0.250
4	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
5	Lower adduttance	0		25.000			0	0.040

RESISTANCE = 0.745 m²K/W	**AREIC HEAT CAPACITY**(sup) = 19.226 kJ/m²K	**TRASMITTANCE** = 1.343 W/m²K
THICKNESS = 100 mm	**AREIC HEAT CAPACITY** (inf) = 25.228 kJ/m²K	**SURFACE MASS** = 28 kg/m²
PERIODIC TRAMITTANCE = 1.44 W/m²K	**MITIGATION FACTOR** = 0.97	**DISPLACEMENT** = 1.49 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

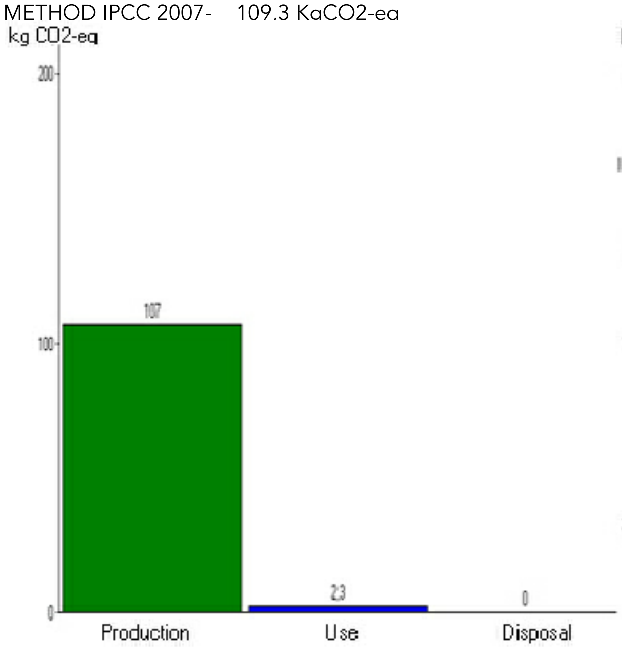


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

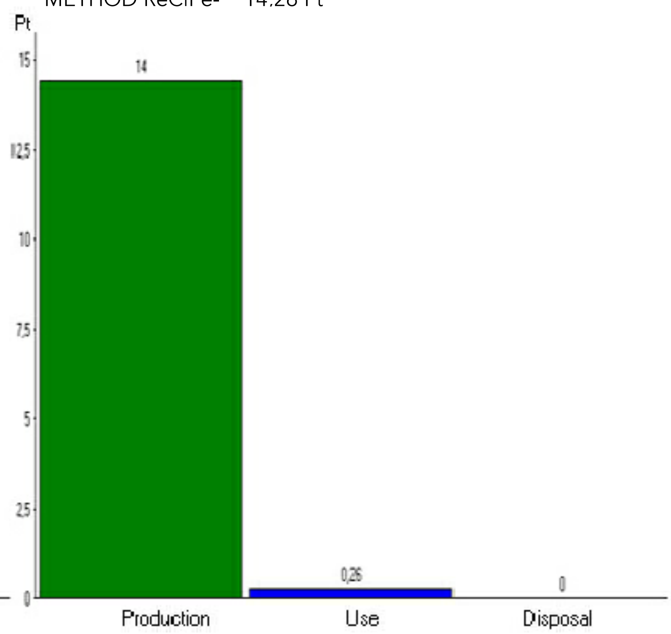
Life Cycle Assessment

COs_3c

METHOD IPCC 2007- 109.3 KgCO2-eq



METHOD ReCiPe- 14.26 Pt



Upper horizontal closure n_4

COs_4

COMPONENTS

Wooden elements

120x25 mm

50x50 mm

200x50 mm

The length of the boards is uniform

Sheet

Corrugated sheet h 50 mm, distance 250 mm

Steel connections

Screw 8x180 mm

Screw 6x70 mm

Bracket 150x150 mm

Screw 5x40 mm

Bolt, nut and locknut

Band

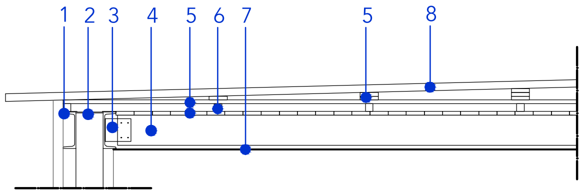
Polyester h 75 mm

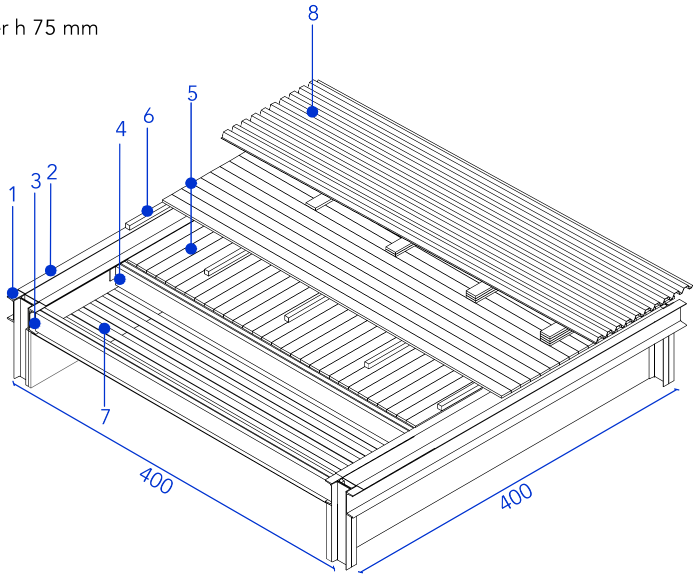
Steel profiles

UPN 240

Closure profile

CONSTRUCTIVE DETAIL





1- UPN 240
2- closure profile
3- bracket 150x150 mm
4- beam 200x50 mm
5- board 120x25 mm
6- wooden element 50x50
7- polyester band
8- corrugated sheet

scale 1:50

variation a

COs_4a

COMPONENTS

Wooden elements

120x25 mm

50x50 mm

200x50 mm

The length of the boards is uniform

Sheet

Corrugated sheet h 50 mm, distance 250 mm

Steel connections

Screw 8x180 mm

Screw 8x120 mm

Bracket 150x150 mm

Screw 5x40 mm

Bolt, nut and locknut

Band

Polyester h 75 mm

Steel profiles

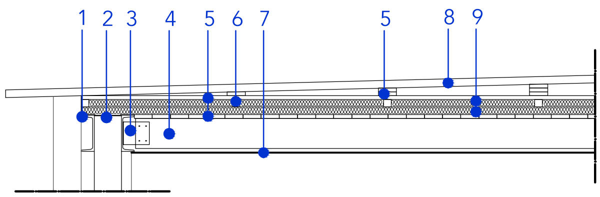
UPN 240

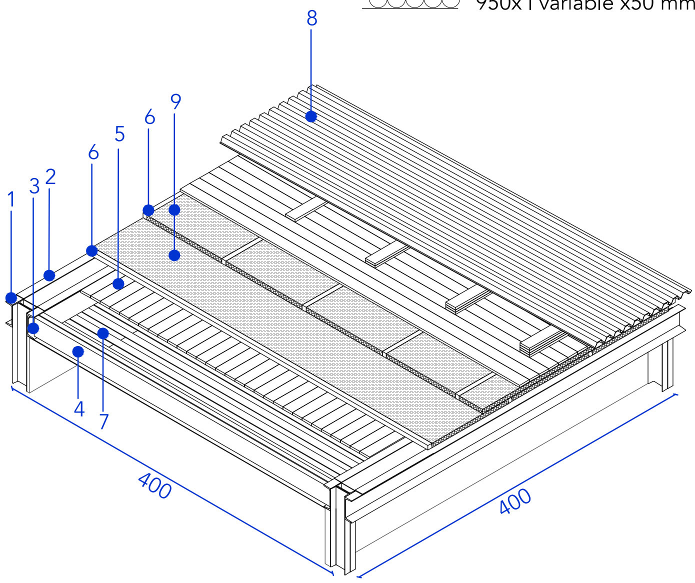
Closure profile

Insulation

Sheep wool 950x l variable x50 mm

CONSTRUCTIVE DETAIL



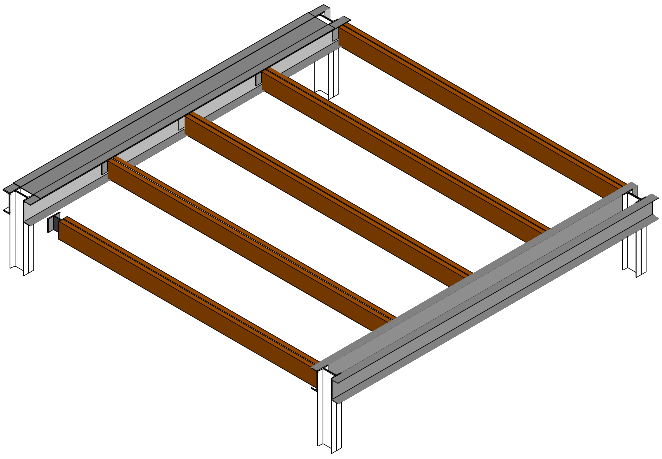


1- UPN 240
2- closure profile
3- bracket 150x150 mm
4- beam 200x50 mm
5- board 120x25 mm
6- wooden element 50x50
7- polyester band
8- corrugated sheet
9- sheep wool

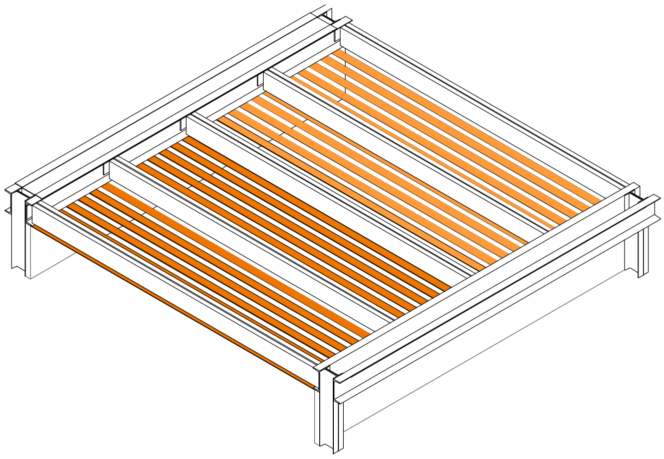
scale 1:50

ASSEMBLY STEPS

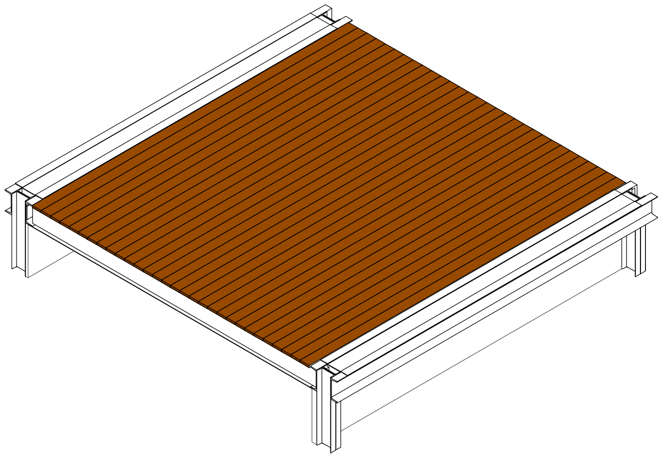
STEP_1
Assembly of load-beam structure



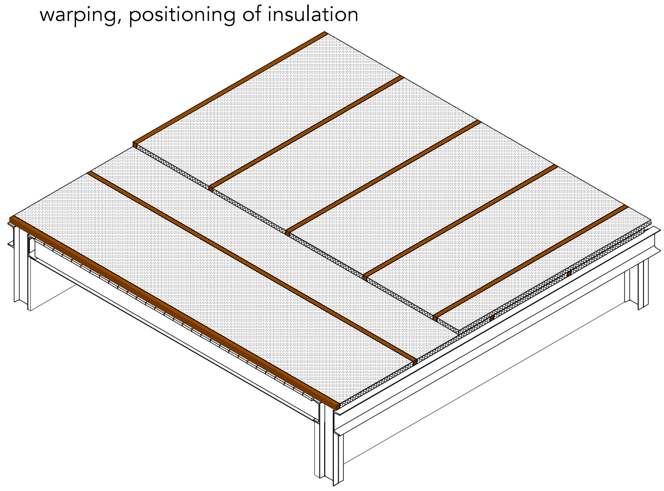
STEP_2
Assembly of the polyester bands through screwing to the vertical closure



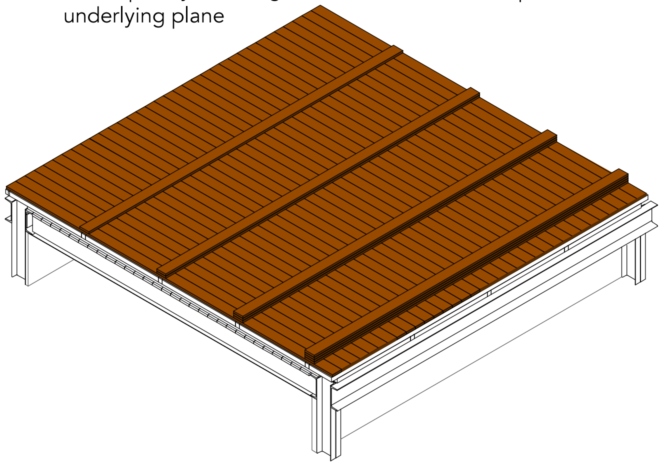
STEP_3
Screwing of the boards to the beams



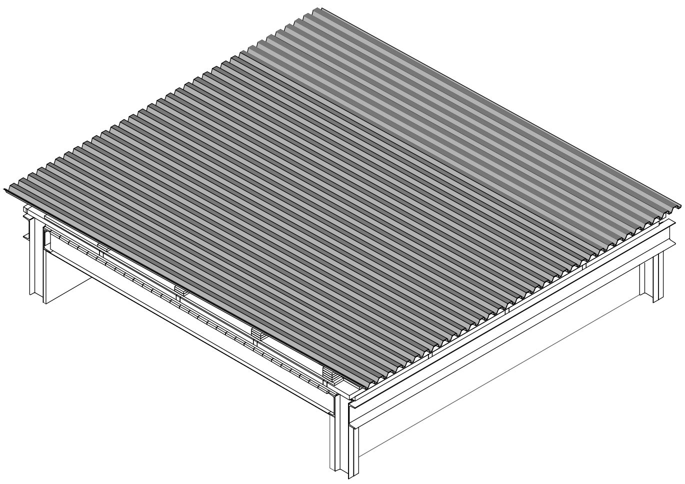
STEP_4
Screwing of the wooden elements with cross warping, positioning of insulation



STEP_5
Screwing of the board to the wooden elements and subsequently screwing of the boards for the slope to the underlying plane

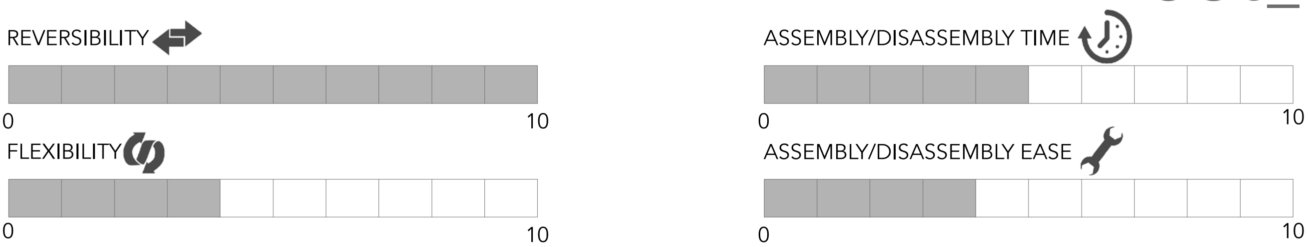


STEP_6
Assembly of corrugated sheet



Technology assessment

COs_4



Environmental comfort

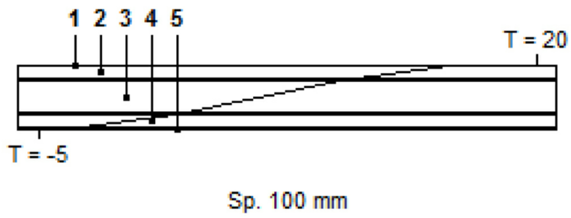
COs_4

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

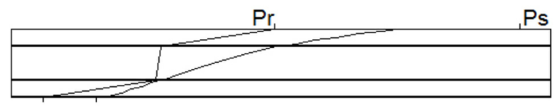
N.	Layer	s [mm]	lambda [W/mK]	C [W/m^2K]	M.S. [kg/m^2]	$P<50*10^{12}$ [kg/msPa]	C.S. [J/kgK]	R [m^2K/W]
1	Higher adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Slightly ventilated horizontal air layer	50	0.200	4.000	0.05	193.000	1008	0.250
4	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
5	Lower adduttance	0		25.000			0	0.040

RESISTANCE = 0.745 m^2K/W	**AREIC HEAT CAPACITY** (sup) = 19.226 kJ/m^2K	**TRASMITTANCE** = 1.343 W/m^2K
THICKNESS = 100 mm	**AREIC HEAT CAPACITY** (inf) = 25.228 kJ/m^2K	**SURFACE MASS** = 28 kg/m^2
PERIODIC TRAMITTANCE = 1.44 W/m^2K	**MITIGATION FACTOR** = 0.97	**DISPLACEMENT** = 1.49 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

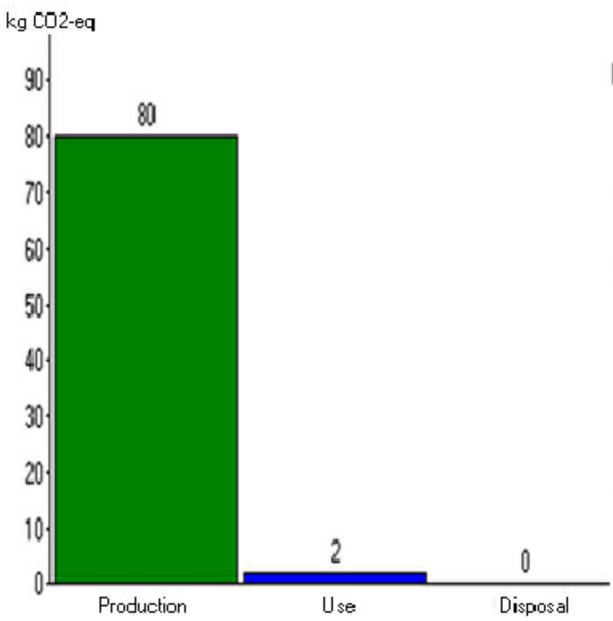


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

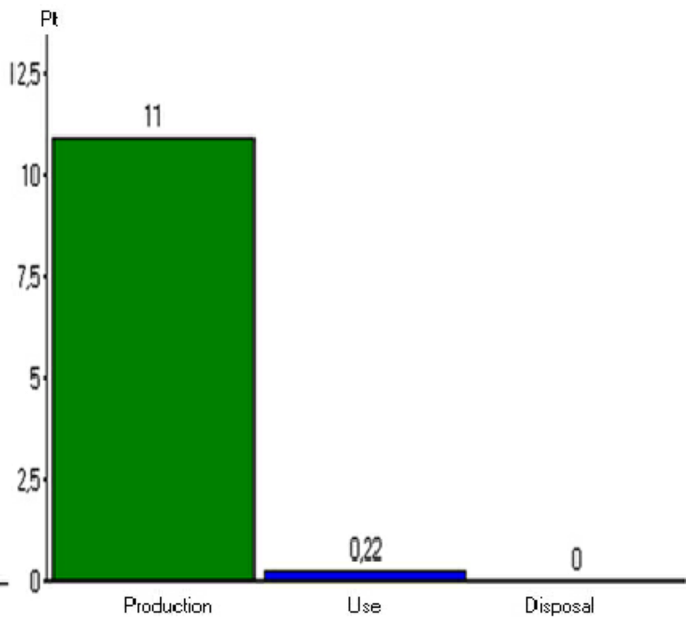
Life Cycle Assessment

COs_4

METHOD IPCC 2007- 82,0 KgCO2-eq

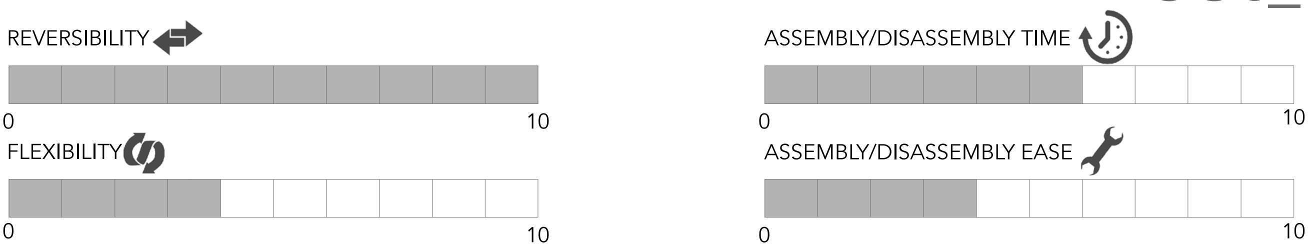


METHOD ReCiPe- 11,22 Pt



Technology assessment

COs_4a



Environmental comfort

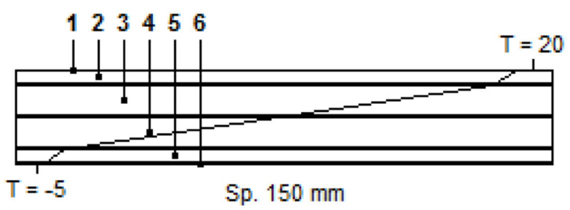
COs_4a

Municipality of L'Aquila, Climatic Area: E , Day degrees: 2514

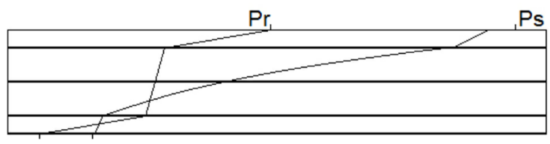
N.	Layer	s [mm]	lambda [W/mK]	C [W/m²K]	M.S. [kg/m²]	P<50*10¹² [kg/msPa]	C.S. [J/kgK]	R [m²K/W]
1	Higher adduttance	0		7.700			0	0.130
2	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
3	Sheep wool insulation	50	0.032	0.636	1.50	96.500	1300	1.572
4	Sheep wool insulation	50	0.032	0.636	1.50	96.500	1300	1.572
5	Pine boards	25	0.154	6.160	13.75	4.500	1660	0.162
6	Lower adduttance	0		25.000			0	0.040

RESISTANCE = 3.639 m²K/W	**AREIC HEAT CAPACITY** (sup) = 22.941 kJ/m²K	**TRASMITTANCE** = 0.275 W/m²K
THICKNESS = 150 mm	**AREIC HEAT CAPACITY** (inf) = 24.720 kJ/m²K	**SURFACE MASS** = 31 kg/m²
PERIODIC TRAMITTANCE = 0.26 W/m²K	**MITIGATION FACTOR** = 0.93	**DISPLACEMENT** = 2.69 h

STRUCTURE



DIAGRAMS OF THE PRESSURES

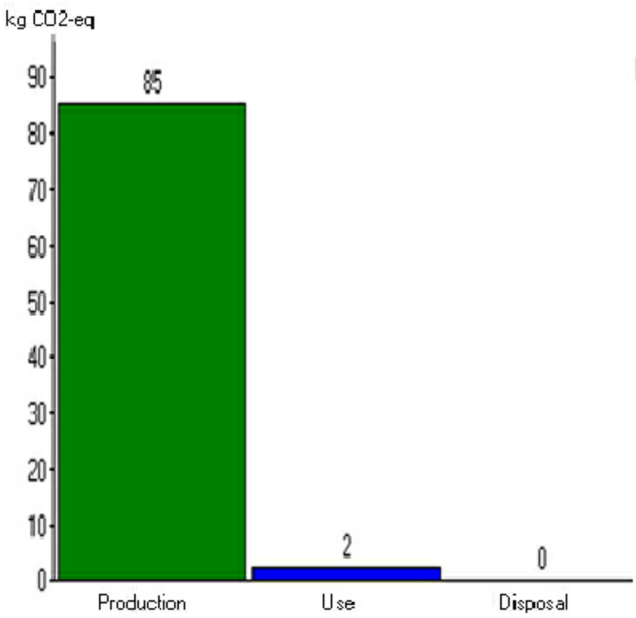


	Ts [°C]	Pss [Pa]	Prs [Pa]	URs [%]	Ti [°C]	Psi [Pa]	Pri [Pa]	URi [%]
DIAGRAMS OF THE PRESSURES	20.0	2 337	1 215	52.0	-5.0	401	160	39.8

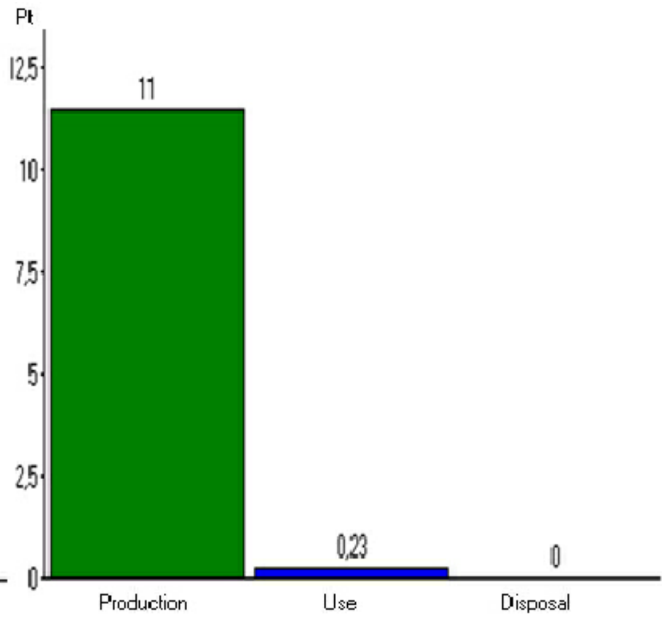
Life Cycle Assessment

COs_4a

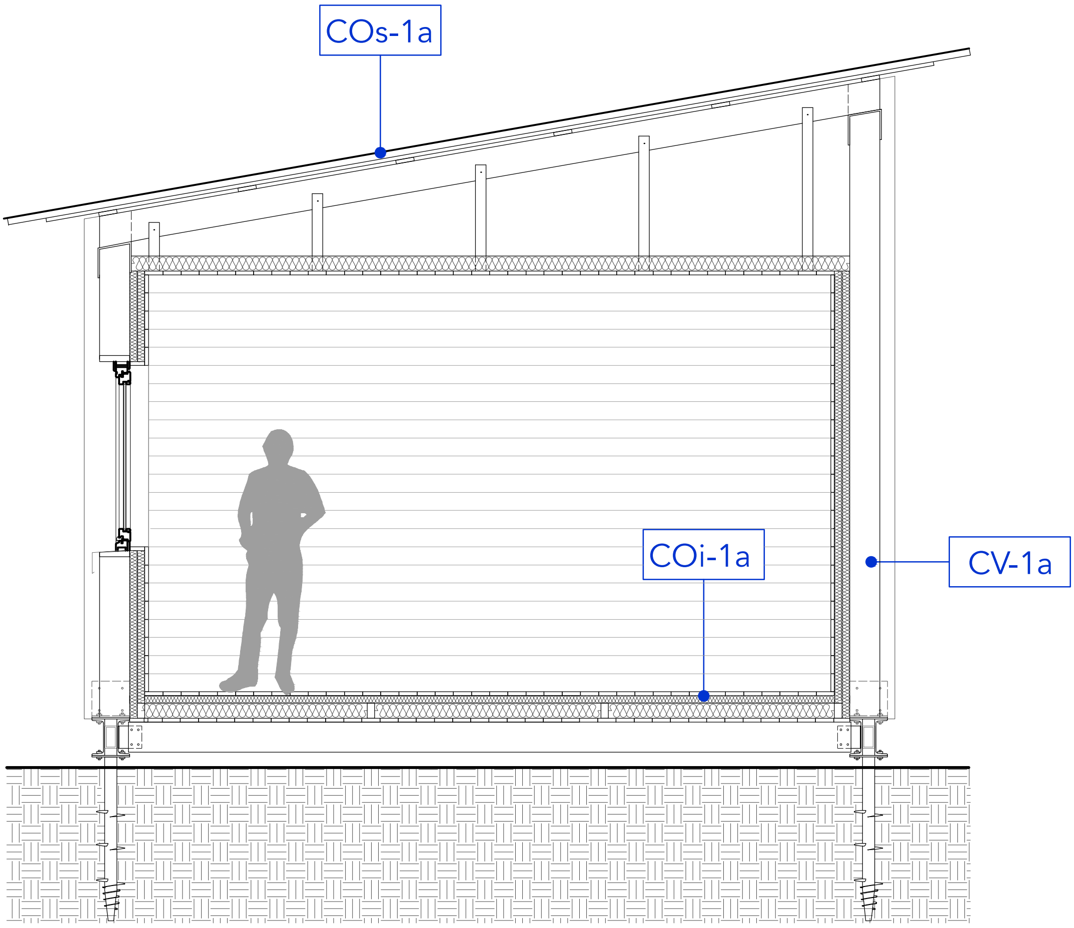
METHOD IPCC 2007- 87,0 KgCO2-eq



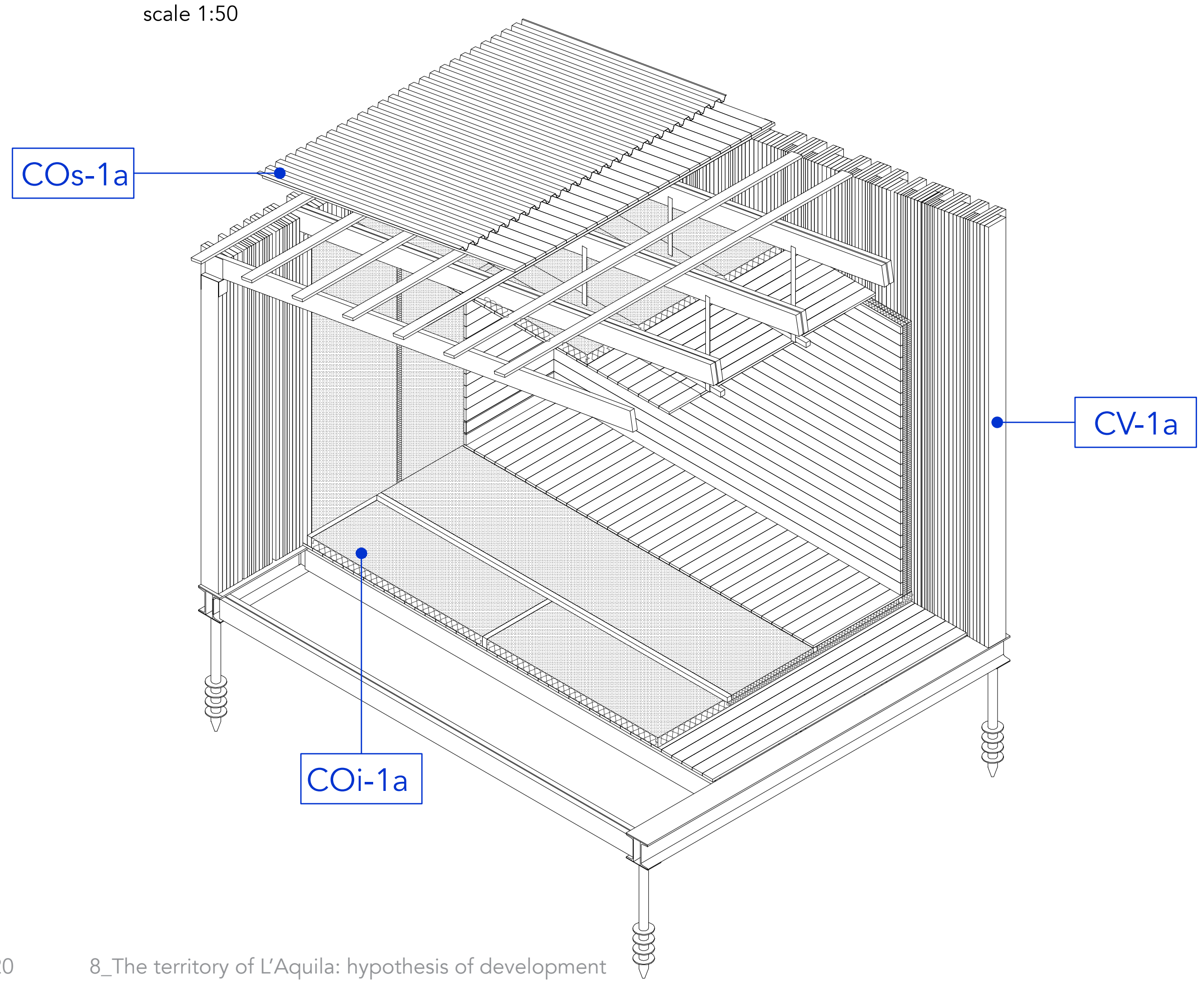
METHOD ReCiPe- 11,23 Pt



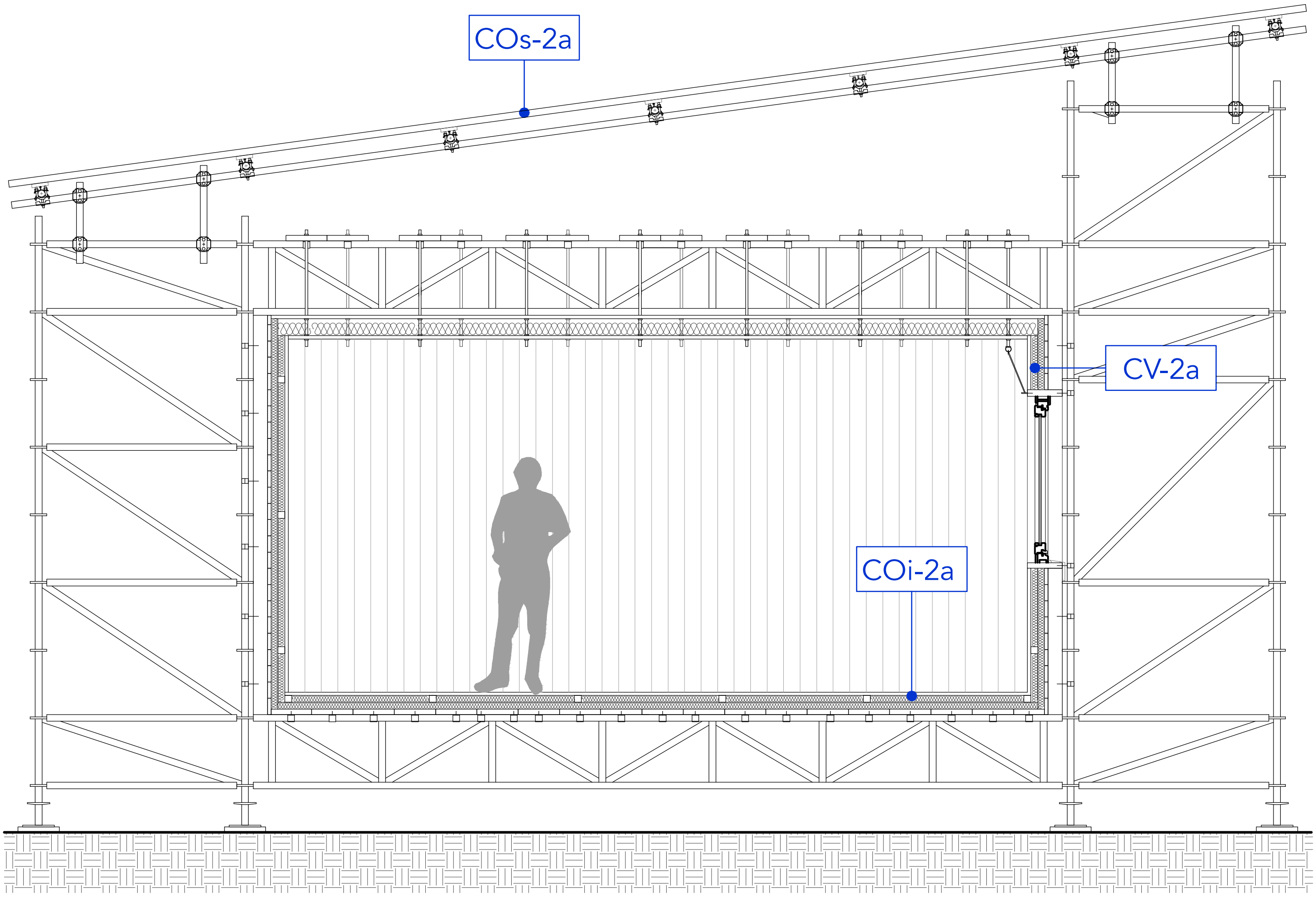
Constructive system CV_1a COi_1a COs_1a



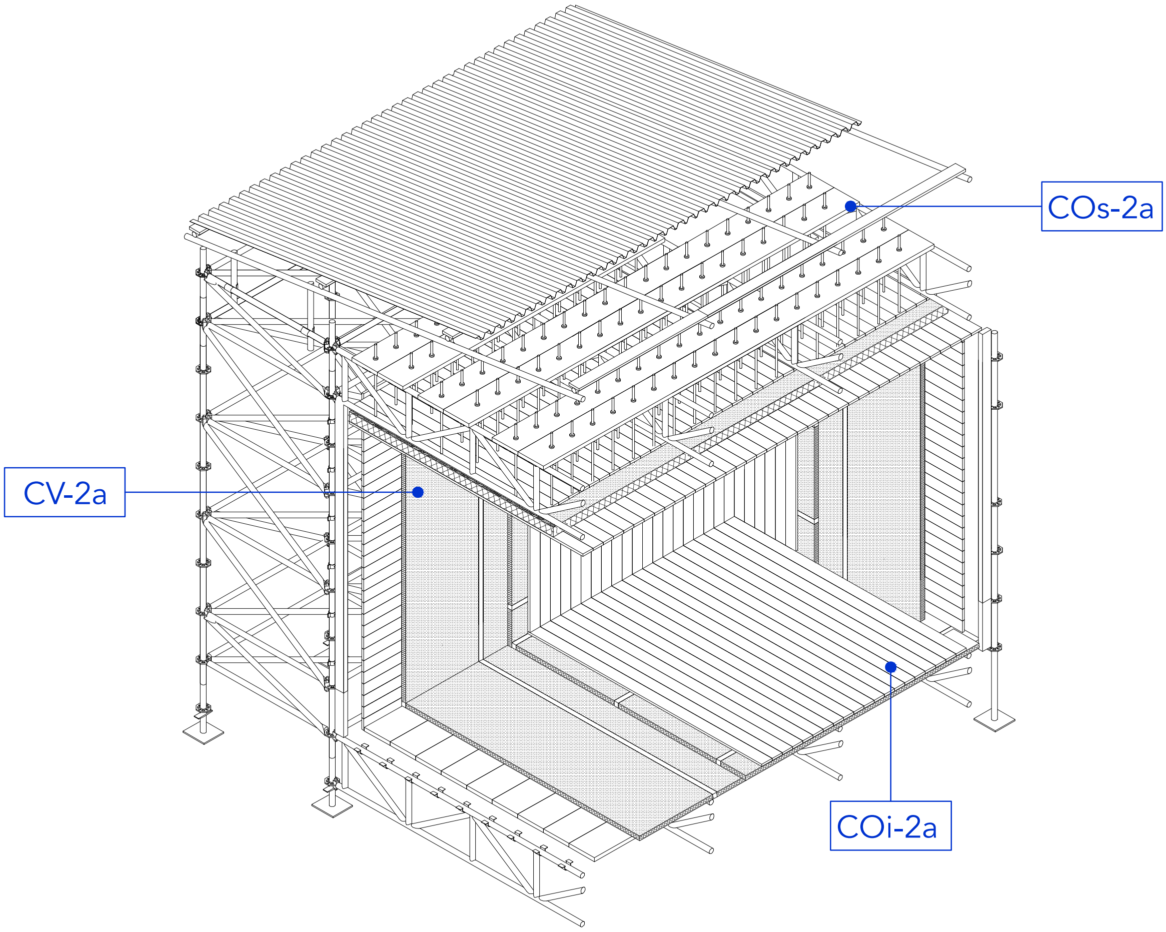
scale 1:50



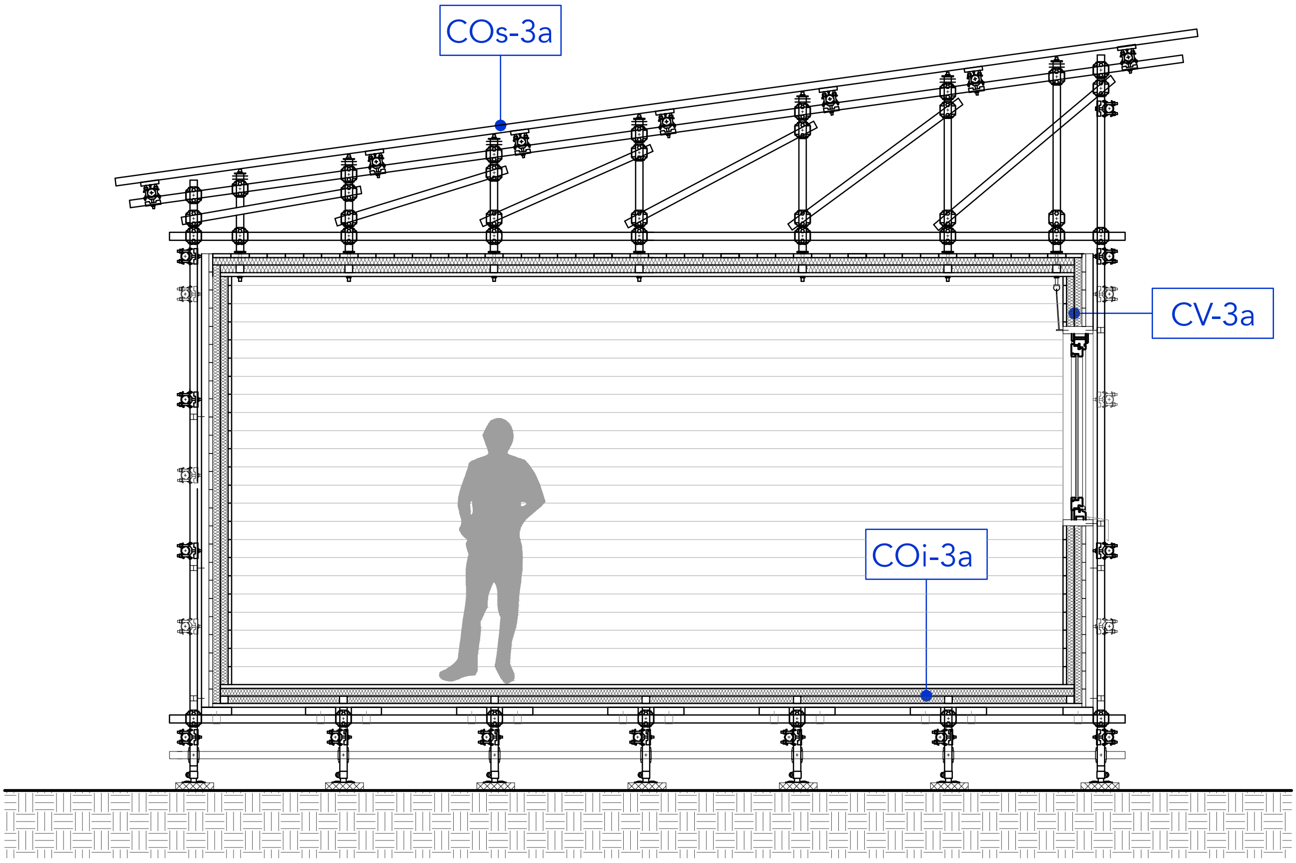
Constructive system CV_2a COi_2a COs_2a



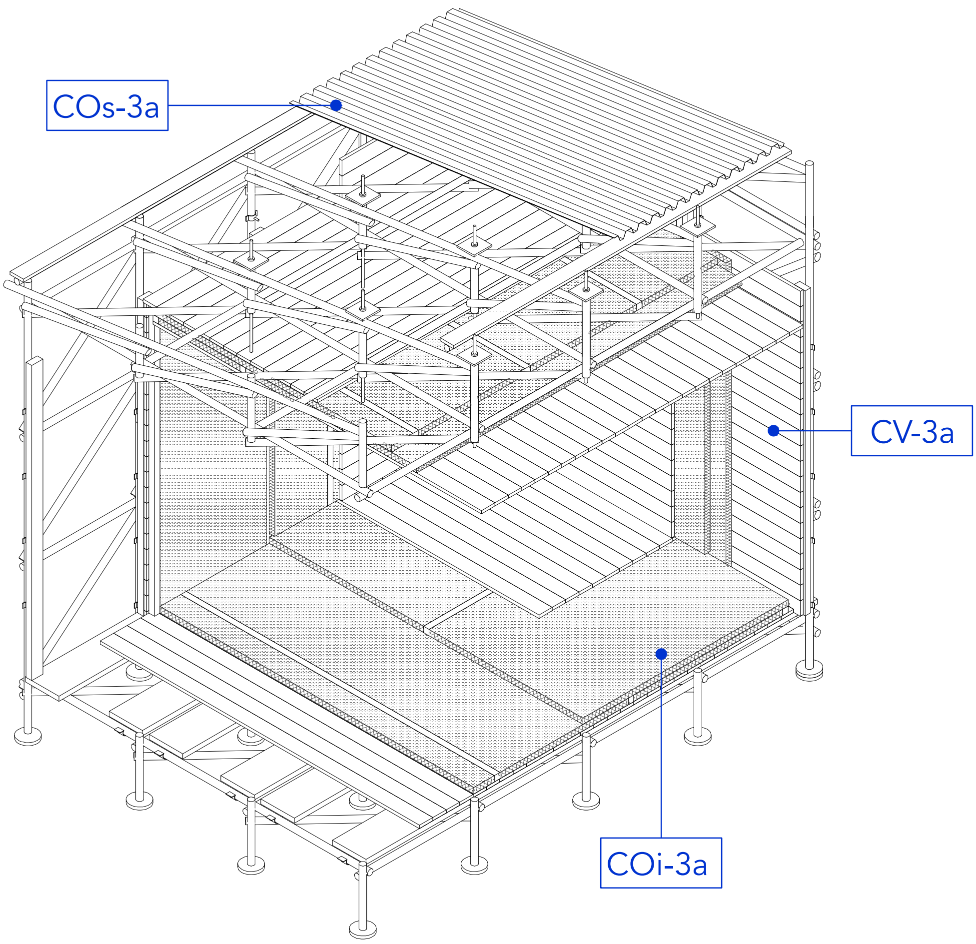
scale 1:50



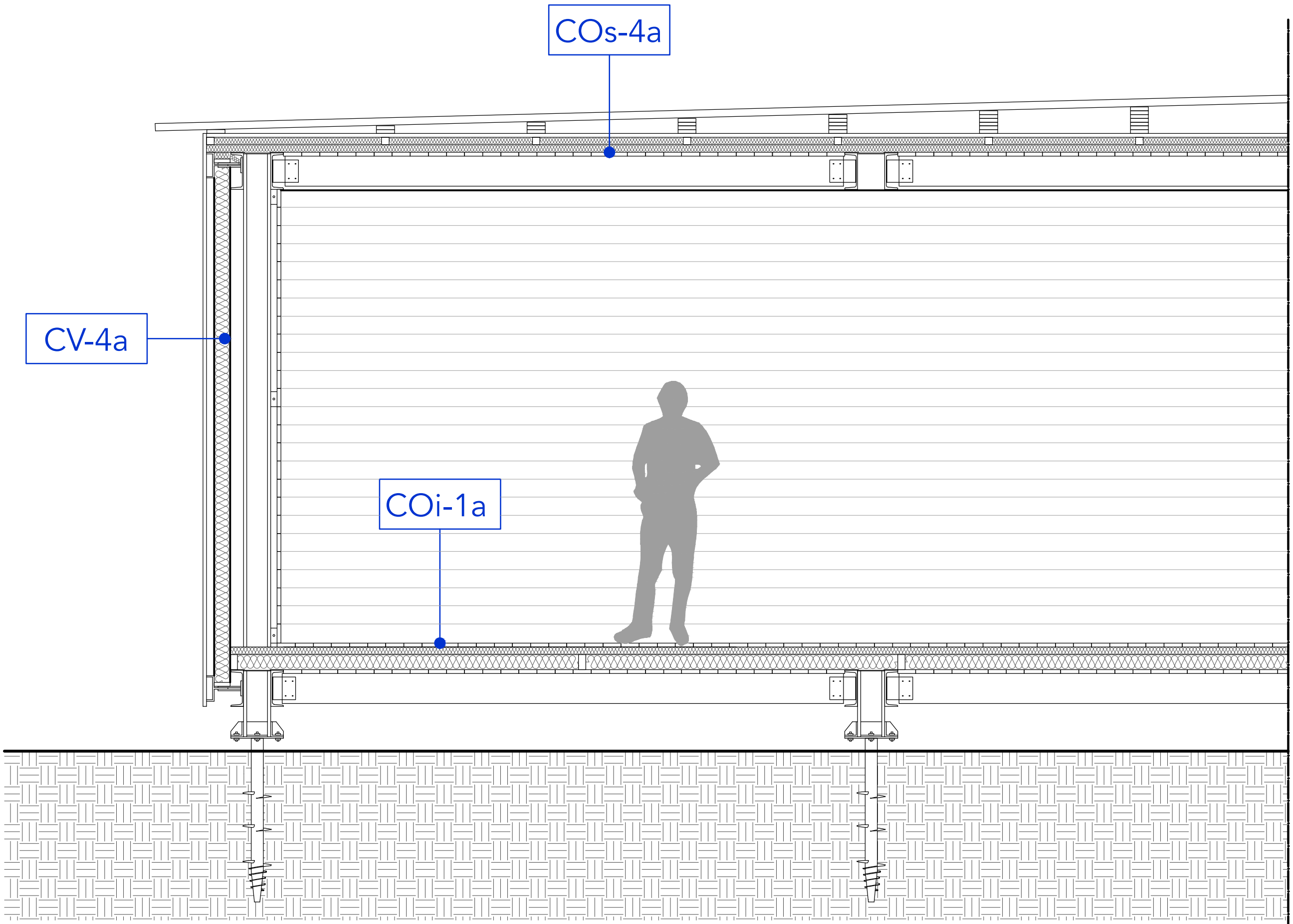
Constructive system CV_3a COi_3a COs_3a



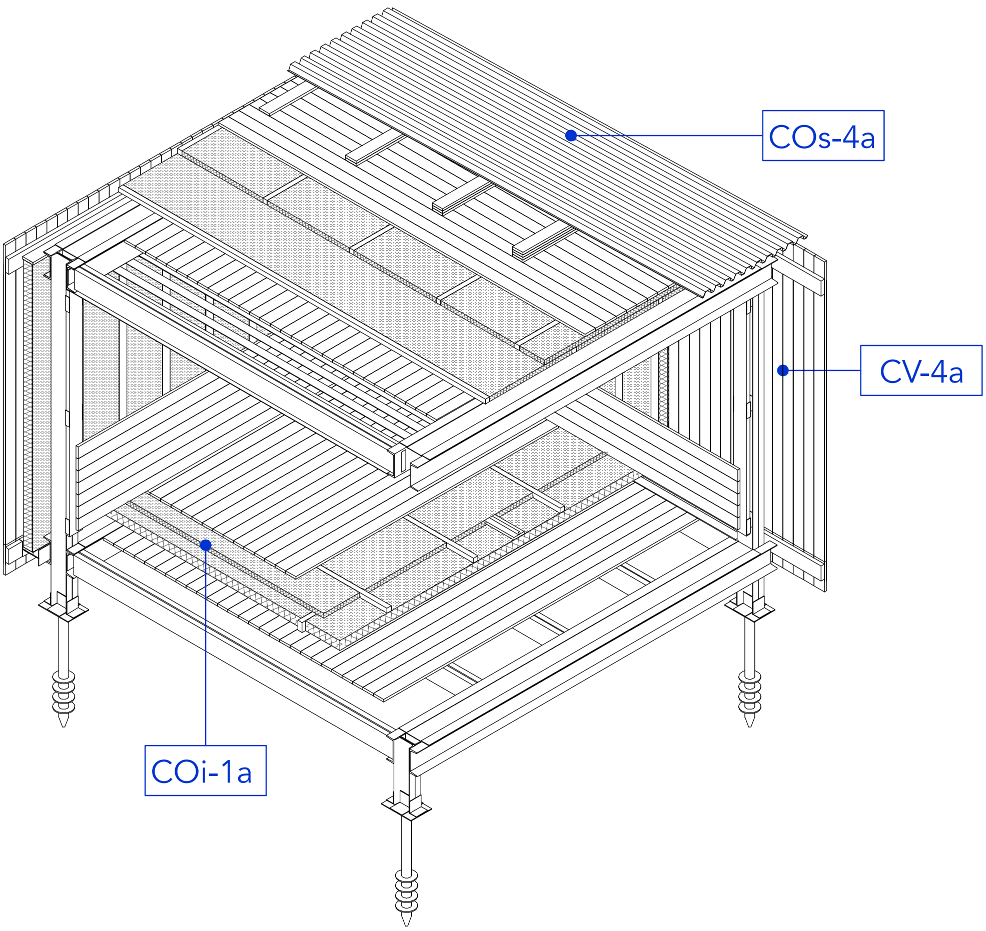
scale 1:50



Constructive system CV_4a COi_1a COs_4a



scale 1:50



A comparison between the systems

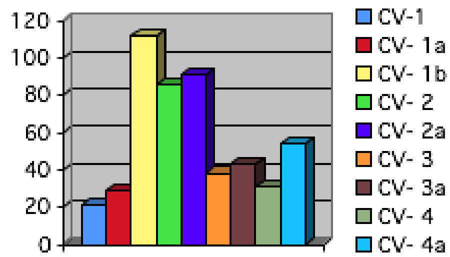
The four construction systems illustrated in tabs SC1, SC2, SC3 and SC4, represent the most obvious mode for parts connection, i.e. based on choices of uniform components. It is possible, however, to identify the existing compatibility between the parts of the building system that have non-homogeneous elements among them, for the purpose of their joint use in the definition of the construction organism. The compatibility must be both of a constructive type, i.e. the parts of the systems must be coupled, and a thermal-hygrometric type, i.e. they must ensure the permanence of the same environmental standard without giving rise to significant differences of insulation.
In the following table, the vertical closures are related with the horisontal minor closures, assuming that in function of the material availability and the definition of the construction organism, the same vertical closure can be related with different horizontal closures.

	CV 1	CV 1a	CV 1b	CV 2	CV 2a	CV 3	CV 3a	CV 4	CV 4a
COi_1									
COi_1a									
COi_2									
COi_2a									
COi_3									
COi_3a									
COi_3b									
COi_3c									
COs_1									
COs_1a									
COs_2									
COs_2a									
COs_2b									
COs_2c									
COs_3									
COs_3a									
COs_3b									
COs_3c									
COs_4									
COs_4a									

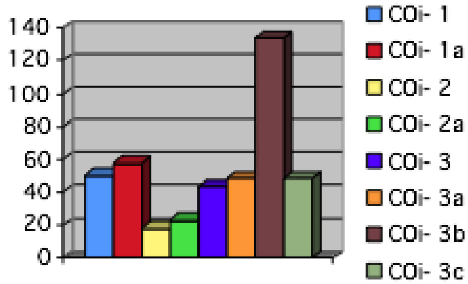
The possibility also exists to build a constructive organism that presents different vertical closures, as long as both are compatible with the some horisontal closures. The compatibility with the horisontal closures is, therefore, a parameter for identifying the usage opportunity of two different systems of vertical closures. For example, the CV2 and the CV3 are both compatible with the closure COi2 and the COs3a and they can be used in the definition of the same constructive organism.

The environmental assessments show the convenience of the reuse for the elements that constitute the safety systems for the construction of the building organism. The IPCC 2007 calculation method they identifies the following values reported to the functional unit that in such case is equal to 1 sqm.

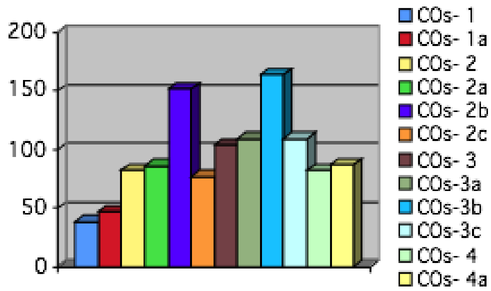
Vertical closures



Lower horizontal closures



Upper horizontal closures



Between the vertical closures the lowest value for the system made exclusively in wood is found, with sole exception of the connectors (CV- 1). The addition to the same system of polycarbonate panels of thickness of 10 m involves an increase in the environmental impact equal to about 5 times (CV-1b). Between the inferior horizontal closures, the structure consists of multidirectional trusses, and presents a lower environmental impact (COi-2), while the structure made of tube-clamps and structural steel C profiles presents a greater impact (COi-3b), with an increase of 86% in environmental damage. Such differences depend on the presence in the second case of a larger amount of steel per square metre. The trusses, in fact, are born with the function to ensure the same load-bearing function with a minimum use of material, thanks to their resistance to shape. Therefore, the result is linked with the characteristics of the analysed constructive systems. Between the upper horizontal closures, the structure made by load-bearing wooden elements (COs-1) presents a lower impact, while the greater impacts are made by the structures that have steel-coupled C profiles (Cos-2b and

Cos-3b). In this case, they significantly increase the portion of steel present in a functional unit.

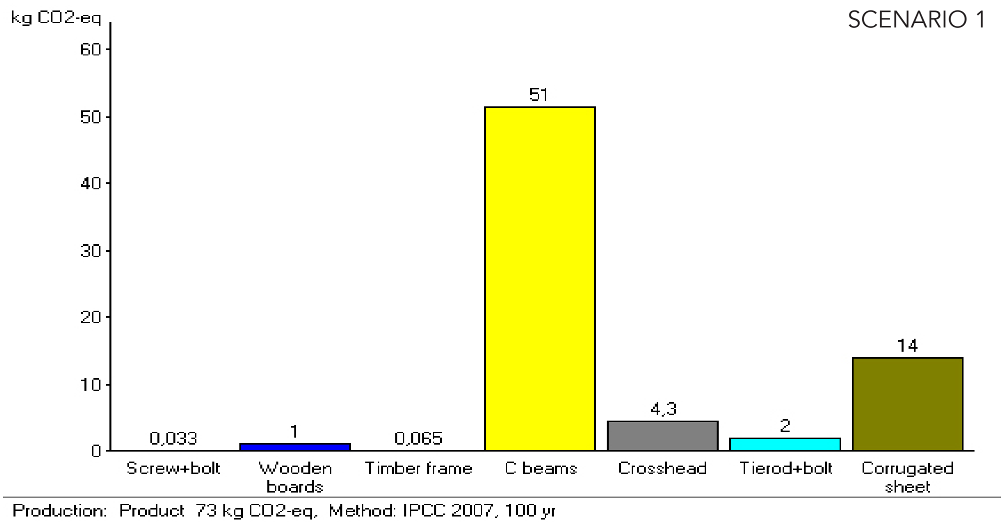
It follows that the steel reuse is an environmental operation more convenient than the reuse of wood, because its production is affected mostly in terms of environmental damage. The reuse amortises the damage over a greater number of years. Otherwise, the added insulation in sheep wool involves, in any case, a percentage increase of the environmental impact included between 5% and the 25% depending on the factory element.

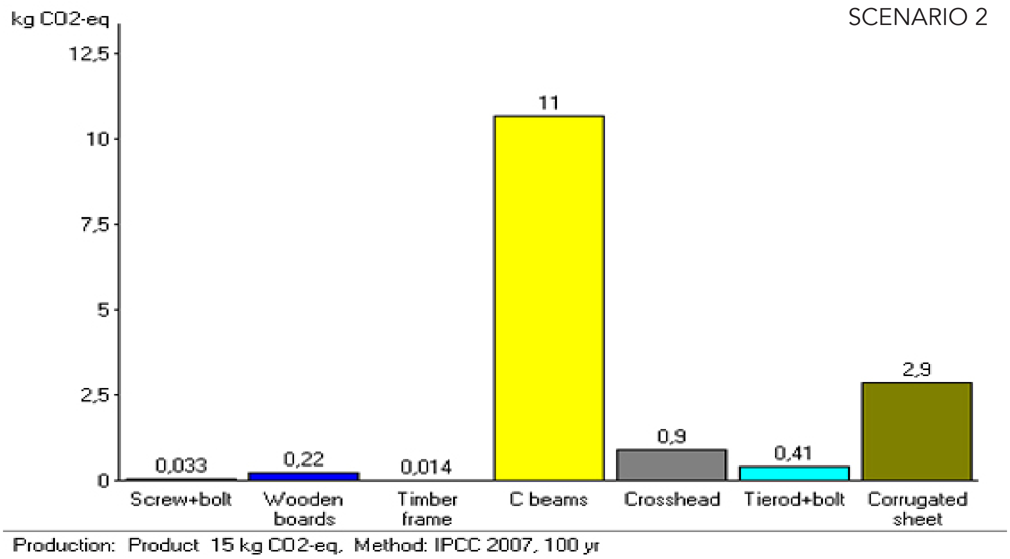
The horizontal closure COs-3b, according to assessments, presents a much higher environmental impact compared to other closures equal to 163.8 kgCO2eq (method IPCC2007-100 years).

Taking as reference a functional unit equal to 1 square metre, the scenarios described below are compared:

1. Assessment of the environmental impact of the production phase of the materials that are part of the closure COs-3b that come from the demolition of safety systems, considering that they are not reused and, therefore, they undergo a life cycle equal to 6 years (2009-2015), which is added to the environmental impact that comes from the new production of the elements for the definition of the closure COs-3b with durability equal to 15 years. The total annual environmental impact (over 21 years total) is equal to 73 kgCO2eq.
2. Assessment of environmental impact of the production phase of the materials that are part of the closure COs-3b that comes from the demolition of the safety system, considering that they are reused for a further life cycle of 15 years in a temporary structure. Therefore, two cycles of life respectively equal to 6 years (2009- 2015) and equal to 15 years (2015-2030) are considered, in this case, in addition to the environmental savings that results from a greater number of years of use for the elements. The environmental savings that results from the lost production of materials for the second life cycle that results from the reuse must also be considered. The impact that comes from the usage of new connectors produced in the second life cycle must also be measured. The total annual environmental impact is equal to 15 kgCO2eq.

The comparison of these scenarios is evident in terms of the environmental convenience of the reuse. In fact, by considering only the production phase, the total annual environmental impact has a percentage reduction equal to 79.45%, compared to the case where the site services are constructed with the same materials that are newly-produced.





8.4 _The temporary endogenous reuse

At present, there are about 4360 reconstructions[9] only in L'Aquila's municipality, which stretches for 466 km[10]. These data let us imagine the logistical discomfort resulting from the predisposition of the pertinent services of the reconstruction sites.

The materials/components coming from the selective demolitions of the safety systems can be reused immediately within the reconstruction site to define the site services as offices, changing rooms, restrooms, toilets, etc. The services of construction sites have to meet specific requirements in accordance with the legislation and, at the same time, they must present such characteristics to facilitate the logistics of the site, such as the rapidity of assembly and disassembly, the dimensional flexibility, and the adaptability to variable weather conditions. They also must be economic: the company must have the possibility to amortise their cost thanks to possibility of reuse of the same building organism or by the use of economic materials, always satisfying specific requirements. The site services made by the materials/components of the safety systems, therefore, must ensure performances that are comparable or even an improvement compared to those of the prefabricated systems currently present on the market. The economic and environmental convenience, in parity of performance, should entice the company to choose these alternative systems rather than the traditional ones.

The legislation relative to the construction site and the necessary requirements

The study of the legislation inherent the type of construction site services in function of the number of workers, the analysis of the dimensional, constructive and positioning minimum requirements, the assessment of the thermal-hygrometric comfort and of the environmental impact of the prefabricated systems present on the market generally used for the site services, have the aim to identify the minimum parameters for the construction of the site services through the reuse of materials of safety systems in L'Aquila. In Italy, the annex XIII of the Dlgs 81/2008 (Testo unico sulla sicurezza sul lavoro)[11] provides the prescriptions for hygienic-sanitary services available for the workers on the construction site. It has to provide a sufficient area to permit the use of site services in safe conditions, separated from the areas of greater operability. It also has to be prepared for the connection to the power grid, water supply and sewerage. The hygienic and sanitary services on the construction site are:

- restrooms (separated by sex):
  - toilets: at least 1 toilet for every 10 workers working on site; for particular requirements it is possible to use chemical toilets or to activate agreements with suitable facilities nearby, open to the public;
  - wash basins: at least 1 wash basin (with hot and cold running water and means to clean and to dry) for every 5 workers working on site; for particular requirements it is possible to activate agreements with suitable facilities nearby, open to the public;
  - showers: at least 1 shower (equipped with heating in the cold season, with hot and cold running water and means to clean and dry) for every 10 workers working on site;
- changing rooms: minimum internal height 2.40 metres; ventilation, lighting and heating in cold season, it has to ensure to every workers the possibility to lock away his clothes during work are required;
- refectories: minimum internal height 2.40 metres; ventilation, lighting and heating in cold season, the supply of cold drinking water, the provision of equipment to heat and maintain the food and eventually equipment to prepare the meals have to be ensured;
- relax rooms, dormitories: minimum internal height 2,40 meters; minimum internal height 2.40 metres. It has to ensure ventilation, heating in cold season, the supply of cold drinking water; in case of stable dormitories they have to be equipped with toilets.

For the definition of constructive features and of minimum sizes, even if the Dlgs 81/2008 does not present explicit references, it is possible to consider the DPR n.320/56[12] (Norme per la prevenzione degli infortuni e l'igiene del lavoro in sotterraneo), as it provides guidance for the work in circumstances that requires increased safety measures with respect to work in open air site:

- housings: they have to be equipped with a bed (or a cot), clothes hangers, seat and shelf for every worker, having a volume of at least 10 mc for every worker, having a free space between a seat and the other of at least 70 cm, the clearance between two rows have to present a width of at least 1.50 metres;
- restrooms:
  - toilets: at least n.1 latrine for every 20 workers;
  - wash basins: at least 1 washbasin for every 5 workers employed in each works, the jets of water should be kept at a distance of almost 50 cm;
  - showers: at least 1 for every 25 workers on sites that occupy more than 100 workers, every shower place has to cover an area of almost 1 sqm, every shower place has to have an adequate space to undress with seat and clothes hangers, the floor has to be waterproof, which ensures the flow of water and be equipped with a wooden grill;
  - changing rooms: required in construction sites where there are more than 20 workers;
  - canteens: required in construction sites where there are more than 50 workers and of which at least 10 make such request;
  - refectories: required on construction sites where workers also consume a meal at work;
  - living rooms: required in construction sites where at least 200 workers are housed. If the number of workers is less than 200, the refectory has to be able to be used as a living room;
  - first aid: up to 100 workers it is required the provision of a first aid kit, for a number of workers greater than 100 and when the distance from public places of first aid do not ensure the timely assistance, it requires a special room with sanitary equipment and with latrines and washbasins;

- infirmary: equired in construction sites with a number of workers equal to 500, in addition to the first aid, it has to provide an infirmary room with 2 beds if the construction site has a number of workers less than 100 and 4 beds in case of number workers above 100; the inspectorate may waive the obligation when there is a hospital nearby.

Next, a summary table considers the conditions that are more precautionary than that reported in the two regulations mentioned above.

Service	Obligatoriness	Features	Dlgs
Toilets	n.1 every n.20 workers (alternative agreements with surrounding structures the construction site)	Water toilet- chemical toilet	81/2008
Showers	n.1 every n.10 workers	Heating- Running cold and hot water- Means to clean and dry	81/2008
		Area of 1 square meter for each shower Allocation of space to undress with stoole and coat rack- Waterproof floor- Runoff of water- Wooden grid support	179/2009
Wash basins	n.1 every n.5 workers (alternative agreements with surrounding structures the construction site)	Running cold and hot water - Means to clean and dry	81/2008
		Jets of water at a distance of almost 50 cm	179/2009
Changing room		H min: 2,40 m- Ventilation - Lighting- Heating Furnitures to ensure to every workers the possibility to lock away his clothes during work	81/2008
	Required on construction sites where there are more than 20 workers.		179/2009
Refectory		H min: 2,40 m- Ventilation - Lighting- Heating- Drinking water- Equipment to heat and maintain the food - Equipment to prepare meals (if any)	81/2008
	Required on construction sites where workers also consume a meal at work.	If the number of workers is less than 200, the refectory must be able to be used as a living room.	179/2009
Relax room, dormitories		H min: 2,40 m- Ventilation - Lighting- Heating- Drinking water - Restrooms (in case of stable dormitories)	81/2008
Housings	Exemption from the obligation housing in case of: proximity and responsiveness of residential areas, small number of workers, works of brief duration	Bed (or cot), seat, shelf for each worker- Volume of 10 cubic meters for each worker- Free space between a place and the other 70cm Space between two rows 1,5 m	81/2008
Canteen	Required in construction sites where more than 50 workers are housed and at least 10 request it		179/2009
Living rooms	Required in construction sites where more than 200 workers are housed		179/2009
First aid	Required until 100 workers	First aid kit	179/2009
	Required in construction sites where there are more than 50 workers and when the distance from public places of first aid does not guarantee the timely assistance.	Emergency room with bathroom equipment, toilet and washbasin	
Infirmary	Required in construction sites with a number of workers equal to 500. The Inspectorate may waive the obligation of the infirmary when there is a hospital nearby.	n. 2 beds (n. workers less than 1000) n. 4 beds (n. workers exceeding 1000)	179/2009

For what concerns the construction requirements, the preparations intended for the hygienic-welfare services and for sanitary services according to the Dlgs 179/2009 (Disposizioni legislative statali anteriori al 01/01/1970, di cui si ritiene indispensabile la permanenza in vigore, a norma dell'articolo 14 della legge 28/11/2005, n. 246) must present the followings characteristics:
in reference to the lower horizontal closures:
- to have the raised floor at least 30 cm from the ground with means to prevent the transmission of humidity from the soil;

in reference to the upper horizontal closures:
- to be fitted with an insulated interspace;
- to ensure no penetration of rainwater;

in reference to vertical closures:
- to have perimeter walls for the defence of the atmospheric agents;
- if in wood, to have double walls with a cavity of at least 5 cm;
- if in the masonry or other structures (conglomerates, panels, etc.), they have to ensure thermal insulation;
- to be provided with windows (in case of dormitories, also blackout windows);
- to have at least 1 access door for every 25 workers;

in reference to technical implants:
- to be equipped with heating systems with prohibition of the use of free fire equipment; when the implant is powered by combustion, it is necessary to provide for a system of evacuation of the products of combustion;
- to be equipped with artificial lighting (in case of dormitories lamps night in low light must also be provided);
- to be equipped with water systems, with procurement of drinking water to the extent of at least 15 litres for employed workers and for dayworkers.

For what concerns the positioning requirements, the welfare and hygienic services have to not interfere with the internal viability and with the operability of the site and have to be placed, preferably, outside the range of action of lifting loads. It is a good practice for reasons of safety, of control and logistics to position these services in the perimeter areas neighbouring the entrance, taking into account the implants connections. For what concerns the dimensional requirements, into account of the standardised dimensions of the furnishing elements and minimum spaces of use, necessary for full usability of the environments, it is considered appropriate to use the minimum sizes as shown below:
- office: 7,5 sqm/employee,
- changing room: 2 sqm/employee,
  minimum surface: 6 sqm;
- restrooms: 1,50 sqm/employee, of which:
  - toilet: 1,20 sqm/element,
    minimum size of lower side: 0,90 m.
  - washbasin 0,3 sqm/element;
- doccia: shower: 1,60 sqm/element, of which 1 sqm to shower and 0,6 sqm to undress;
- relax room/refectory: 2 sqm/employee (to compute about the 50% of the present team);
- refectory: 1,4 sqm/employee;
- infirmary: 1sqm/5 employees.

In Spain the reference legislation for the welfare-hygienic services on site is the Real Decree 1627 of 24th October 1997 (and the relative technical guide prepared by the ISHT) that establishes the minimum safety and welfare measures on the construction site.
In particular the annex IV, specifies with reference to the general dispositions:
- first aid:
  - the evacuation of workers in case of necessity of medical cares has to be ensured;
  - one or more points of first aid have be provided in function of the work or of the type of activities, with number of workers greater than 50;
  - the rooms for first aid have to be equipped with installations and of first aid materials;
- restrooms:
  - they have to be provided for both men and women, or to predict for a separate use;
  - they have to be placed so as not to constitute an obstacle for the site operations, nor for the circulation;
  - showers: they are necessary in function to the type of work, they have to be provided with cold and hot running water;
  - wash basins: when the showers are not provided, the washbasins with running water (if necessary hot) are required;
  - toilets: they have to be provided with a sufficient number;
- changing rooms: they have to be present when the workers have to wear special working clothes, they have to present enough space to arrange the settings and equipment as to permit to workers to dry clothes and to separate the personal clothes to those used for working[14], when the changing rooms are not necessary, it is mandatory that every worker can access a locked space where put their personal objects and clothes;
- dormitories/ housings:
  - they have to be provided in function to the type of activity and to the distance from the site, it is mandatory that they have sufficient sizes and are equipped with tables and chairs with backers;
  - in absence of these rooms, it is mandatory that the workers rooms where to spend work breaks;
  - in case of fixed housings, they have to ensure sufficient sizes and to be equipped with hygienic services and places of leisure;
  - measures to avoid the discomfort of non-smokers have to be provided;
- refectories: it is mandatory that the workers have a localised place to eat and prepare meals; they have to be heated in the winter and well insulated. If necessary, it will provide an installation with relative hygienic services.

Near working places, drinking water has to be made available. In addition, the legislation provides indications in reference to the electrical installation, to type of ventilation (natural and artificial), the temperature and lighting.
It is mandatory that pregnant women and nursing moth-

ers have the possibility to rest themselves and the working places have to be organised. When present, disabled workers will also have to be taken into account.
The legislation does not present, however, explicit references to constructive requirements of the welfare-hygienic services, but underline exclusively the necessity of construction elements that are easy to clean and ensure worker safety.
The size requirements can be deduced by the legislation relative to the workplaces, such as Royal Decree 486/1997:

- general features: height min: 2.50 m, surface min: 2 sqm/worker; volume min: 10 mc/worker; ventilation: maximum 0.75m/s not sedentary work in warm place, 0.50 m/s sedentary work in warm place, 0.25 m/s sedentary work in place not hot; temperature: between 17° and 27°; humidity: between 30% and 70%; lighting: areas with low visual exigencies 100 lux, areas of occasional use 50 lux
- changing room : 2 sqm/worker
- shower: n. 1/10 workers (of which at least ¼ in individual cabins)
- wash basin: n. 1/10 workers
- toilets: n.1/25 men , n.1/15 women.

From the comparison, it is clear that, unlike the Spanish legislation, the Italian legislation presents indications that are both less generic and more restrictive, protecting the worker more widely.

Fig. 2 _ Reconstruction sites in the historic centre of L'Aquila

Fig. 3 _Occupation of the road with reconstruction site

Case study: the predisposition of site areas for common use in the historic centre of L'Aquila.

The historic centre of L'Aquila currently addresses issues concerning the interferences between the various construction sites (handling cranes, moving means, predisposition of the site services, storage of the materials, etc.) due to contemporary reconstruction of neighbouring buildings. The small size of roads and the continuous street front, characteristic of the historic centre, do not facilitate the conduct of reconstruction operations.
Always, in fact, the road way is occupied to meet the logistical requirements of the site, becoming part of it and limiting the viability with consequent impact on the speed of reconstruction.
It proposes a methodological/operative procedure that distorts the traditional conception of the site, in favour of a collective dimension, supported by greater attention to the local resources of the territory.
The reduction of the interferences can be resolved through the predisposition of areas for common use of companies and the intervention programming can be carried out simultaneously. The areas for common use must be provided of spaces for the storage of materials coming from the selective demolitions, of equipment of common use, such as cranes and services such as refectories and restrooms. On the one hand, it ensures the reduction of the number of site areas, restoring the viability and, on the other hand, each company has the possibility to operate individually, limiting the contentious.
Within the common areas, spaces for the private use of the companies must be provided such as the offices, changing rooms and a space for the storage of the materials owned to the enterprise. The common areas of the site can be used by the enterprises that deal with the reconstruction of the buildings falling within 100 metres[15].
Besides the observance of regulatory obligations, numerous areas of the territory are identified and the programming of reconstruction interventions results is easier because the number of buildings falling in each area will be reduced.
The installed crane must have a sufficient arm length to reach all buildings present in the area.
The use of the crane is programmed in function of the working phases that must be realised in the individual construction sites, establishing a timetable of competence for individual companies.
The definition of an area within 100 metres and the predisposition of cranes that operate only within the same areas, prevents the occurrence of interferences and favours the contemporary working on reconstruction sites of buildings falling in areas of different influences.
The reduction of environmental damage and of the logistics and economic burden resulting from the loss of reuse of the materials/components that constitute the safety systems can be achieved by providing, after disassembly, an immediate reuse for the construction of the site services. The characteristics of the constructive systems used for the safety, in particular of the systems that born to perform temporary tasks (tube-clamp systems, multidirectional systems), facilitate their reuse.

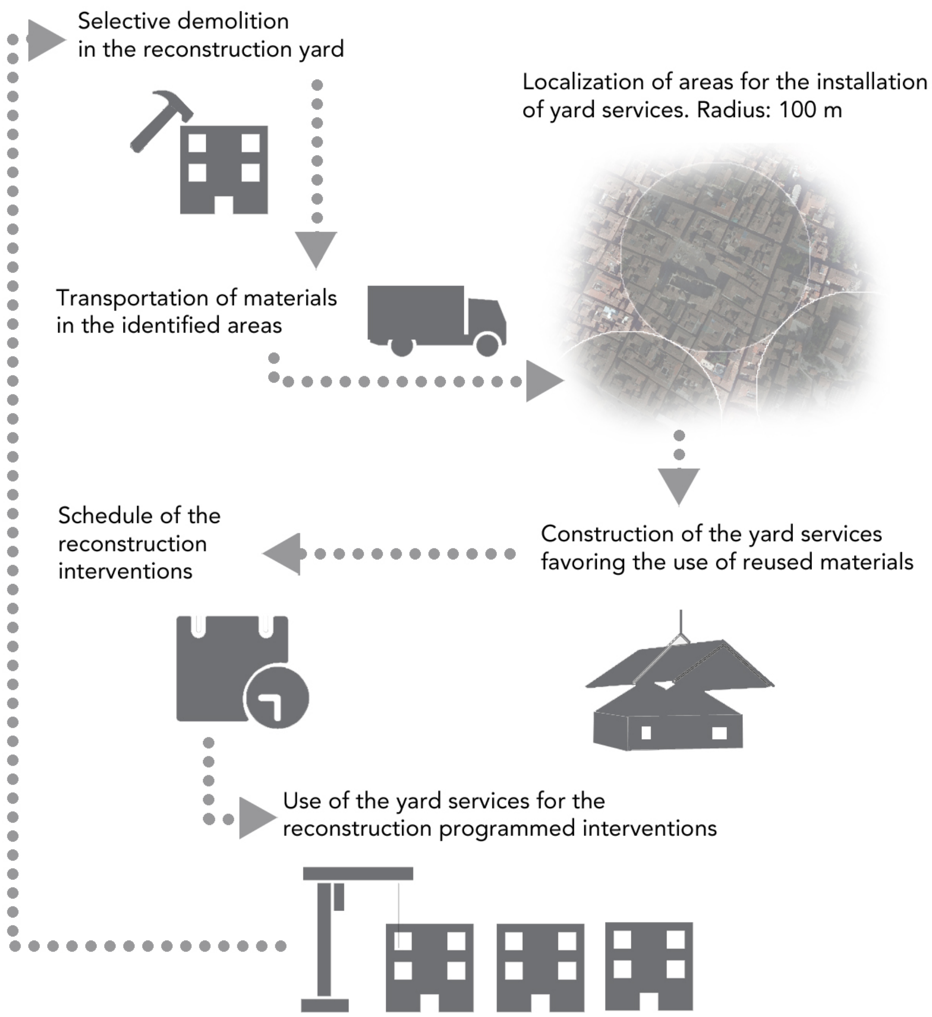


Fig. 4 _ Methodological-operative process of site organization

Design experimentation:
a common site area in Santa Maria Paganica square

The conformation of the urban fabric of the historic centre of L'Aquila, interspersed with numerous squares, allows an easy application of the previously described procedure. To cover the whole surface of the historic centre, 50 areas of site for common use must be prepared. It follows that 50 reconstruction interventions can be realised at the same time, without problems of interferences between sites.

The described procedure is applied, hypothesising the organisation of a common site area in Santa Maria Paganica square, situated in the historic centre. The square has a surface of about 100 sqm. Considering an area of influence within 100 metres from the square, the site is at the service of 25 aggregates[16]. The use of the square is conditioned from the programming of the execution of the restoration intervention of the Church of Santa Maria Paganica as first or last intervention, to avoid the interference between the reconstruction site of the church and the interventions on the aggregates within the range of use of the area. In fact, the latter extending parallel to the length of the church, whose wall constitutes a physical limit. A similar argument should be theoretically done also for Palace Ardinghelli that constitutes the other physical limit of the square. This Palace already has undergone an intervention of reconstruction and it must not be inserted in the programming. Excluding the areas to be allocated to viability, it is possible to build the site services in two areas. An area equal to about 400 sqm is intended for functions and equipment of common use, as restroom, refectory, the crane and a collecting area of residues coming from the selective demolition. The latter has been dimensioned to collect up to 200 mc of material. The other area that has an area of about 2000 square metres is intended for the private functions of the companies such as offices, changing rooms and deposits. In function of the type of interventions of reconstruction that must be performed in such aggregates, the area intended for private functions was organised by providing the contemporary use of three enterprises, each respectively for 10 workers and, therefore, arranging 3 offices, 3 changing rooms and 3 areas of deposits, dimensioned in function of regulatory minimums as previously described. The environmental damage and the cost that derives from the construction of site services, using the materials/components coming from the selective demolitions and from the short supply chain in the territory of L'Aquila are assessed. In addition, the environmental damage and the costs of the predisposition of an area of similar site realised with modular prefabricated systems present on trade are assessed. Between the 25 aggregates falling within the range of use of the site area, the Civic Museum of Santa Maria dei Raccomandati is taken as an experimental reference. The safety systems placed in that museum were analysed according to the methodological-operative procedure described in the previous chapters, both for what concerns the identification of the components that constitute them and for what concerns the optimization of the reuse of wooden and steel components. It is evident that not all materials identified as reusable could be reused for the definition of the services in the common area of the site, as well as they will have to be integrated with materials that come from the disassembly of the safety systems of neighbouring sites of reconstruction or coming from the local supply chain.

Fig. 5 _ Santa Maria Paganica square (07/04/2015)

Fig. 6 _ Identification of buildings within a radius of convenience of use of common site area

Fig. 7 _Localization of the common area (in red) with respect to the Civic Museum of Santa Maria dei Raccomandati (in blue)

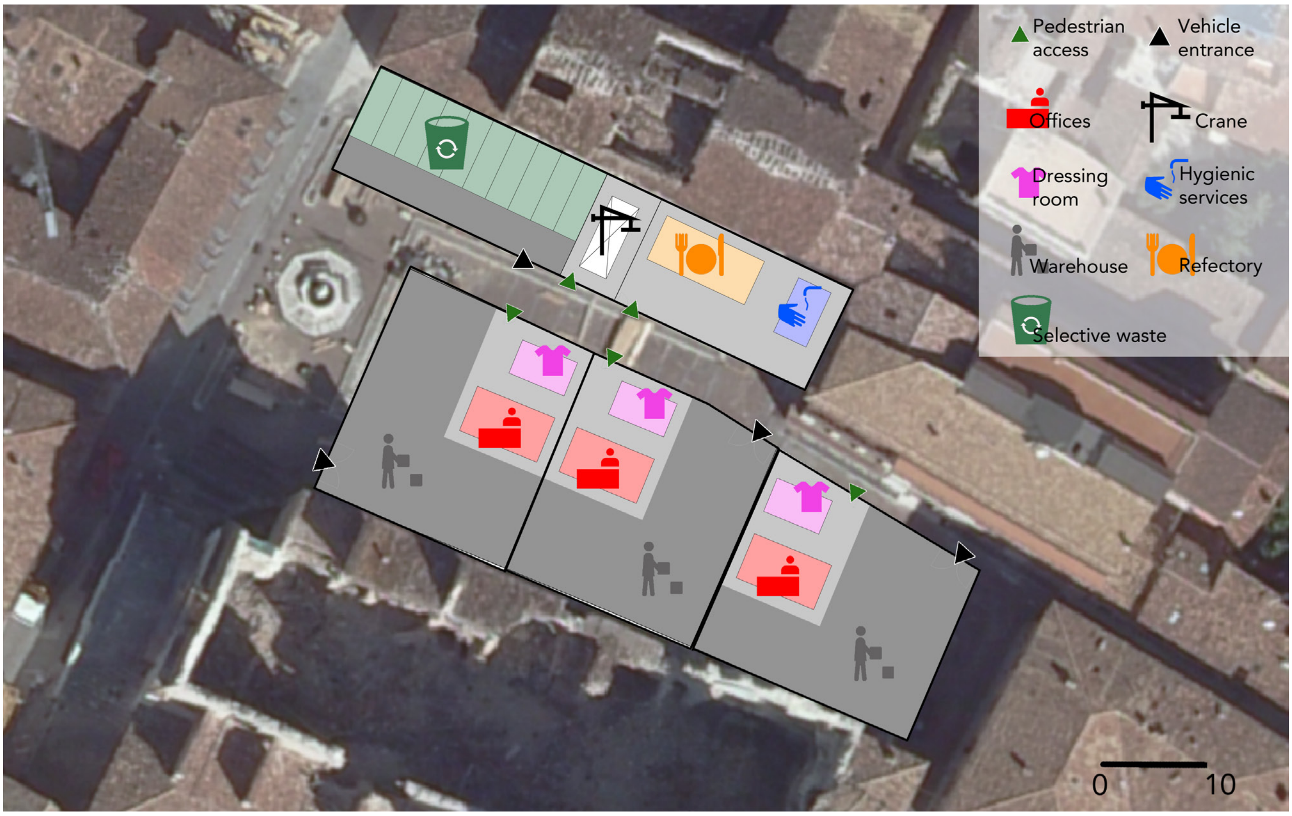


Fig. 8 _ Organization scheme of the site

The Civic Museum of Santa Maria dei Raccomandati: damages and safety systems

The architectonic complex "Santa Maria dei Raccomandati" is located in the historic centre of L'Aquila, at the corner between Vittorio Emanuele Street and Bominaco Street. On the plan "Aggregati edilizi- OPCM 3830/2010 s.m.i. – Allegato Disp. Dir. Prot. 89969 del 13/10/2014," it is identified by the aggregate n.447. Gioacchino Murat suppressed the monastery of Santa Maria dei Raccomandati in 1811[17] aand the property was transferred to the municipality of L'Aquila. It has a neoclassic aspect witnessing the changes that occurred in the second half of the nineteenth century. Within the ex-convent, there is the Church of Santa Maria dei Raccomandati that was constructed in 1825. Before the earthquake, it was supposed to host the Civic Archeologic Museum. It presents a complex articulation, resulting from the changes dictated by the historical evolution of the building, it is on three levels ground floor, mezzanine and first floor with double height in correspondence of the multi-purposes hall and exhibition galleries. It has two accesses, one at the ground floor from Vittorio Emanuele Street and the other at the mezzanine from Bominiaco Street, which gives access to the multi-purposes hall. It presents two courtyards, one of which is covered by a recent structure made with steel and glass.

The earthquake of 6th April 2009 caused extensive damages to the complex, with the consequent necessity to perform safety interventions[18]. An intervention of internal passing system of tie rods (constituted by rods positioned on opposing walls and by the internal passage of the rods) with the aim to contrast the rotation out of the plane of the facade, due to the lack of union between the walls and the floors, witnessed by the numerous subvertical and diagonal cracks, was carried out.

Fig. 9 _ Civic Museum of Santa Maria dei Raccomandati

The façade of Vittorio Emanuele Street has structural problems of lesser importance so it was secured by tie rods using a grid of wooden uprights (20 x 20) and wood crossbeams (14 x 18 cm) connected by plates of size 50 x 50 cm, which act as a retaining members for the steel strands ϕ16 on the opposite side (which insists on the courtyard). The tie rods have been anchored to a grid made with steel uprights HEA 200 and steel crossbeams made with coupled profiles UPN 180 or profiles UPN 200 coupled by welding plates and stringing plates anchored to the wall (6 berths for side) with anchored dowels of iron cast with two component epoxy adhesive resin (thickness 20 mm, length 50 cm). The façades overlooking Bominiaco Street and Accursio Street were secured by tie rods using a structural grid made of uprights HEA 200 anchored to the soil and coupled crossbeams UPN 180, which act as retaining members for the steel strands ϕ16 anchored on opposite sides (which insist on the courtyard) by structural similar grids. In all cases, wooden tables of load distribution disposed to adhering with the masonry and wooden tables designed to overcome the obstruction of frames and beads have been used. Some of the load-bearing walls on the front overlooking the courtyard in correspondence of Accursio Street were encircled by bands of polyester with maximum operating load of 50,000 kg (3 bands for each load-bearing wall) with the inclusion of shaped plates and wooden tables at the edges. The hooping intervention of the load-bearing walls has the aim to contrast the efforts of compression and shear and to prevent bulging. Interventions of shoring support in all the floors, in the barrel vaults, cross vaults and cloister vaults were carried out using different schemes by telescopic props, tube-clamp systems and wooden planks of load distribution between the props and the intrados and between the prop and the decking. In this way, the collapse of the horisontal structures seriously damaged and compromised by cracks is prevented.

In case of painted vaulted ceilings, before the shoring operations the plasters have been consolidated in a localised way and protected by a double layer of Japanese paper.

An operation of support through support structures made of wooden moral (10x10 cm) was performed in correspondence of the openings whose lintel is damaged.

A small portion of coverage was demolished because it was unsafe and it was subsequently replaced with a self-supporting structure in tube-clamp system and corrugated steel sheet. The cost for safety intervention was equal to 581052,48 euros[19].

The qualitative and quantitative analysis of the used safety systems of the building, allows for the identification of the type and dimensions of the potentially reusable elements and to define, consequently, the portion of material that must be initiated to be recycled (in case of steel) or in incineration installations for the recovery of feedstock energy (in case of wood). In the case study, it is possible only to effect a preventive assessment, as the safety systems are actually assembled and to hypothesise a definitive assessment based on the available data through precautionary choices.

The used materials are:

- steel for metal carpentry: S275JR (Fe 430), with ultimate tensile strength fu = 439 N/mmq and yield stress fy = 275 N/mmq;
- timber of 2°category, not resinous; allowable stress: σamm = 102 kg/cmq;
- polyester bands compliant to CENT/TC 168/WG3 prEN 1492-1;
- steel strands with ultimate tensile load 16.100 kg and yield stress fy = 1770 N/mmq.

The analysis of the used connections allows the determination of the reversibility level of the system, which identifies the potentially reusable dimensions of the elements. By taking into account the grids made of steel uprights and crossbeams that insist on more fronts, we identify the following types and modalities of connection:

- the uprights HEA 200 are anchored to ground by insertion in a excavation filled with concrete and placed on a metal plate;
- the uprights HEA 200 are jointed vertically through bolted plates with variable stretch between 6.0 and 7.0 metres;
- the uprights are made integral with masonry through expansion bolts or chemicals dowels;
- on the uprights are welded steel brackets with variable stretch in function of the positioning of crossbeams; the crossbeams, instead, are resting on the brackets and welded to the uprights, also in the corner points of the building the crossbeams are welded to uprights, but without the supports of the brackets;
- the crossbeams are connected between them through bolted plates with a variable distance between 5.0 and 6.0 meters, in the corner points the crossbeams are united by welding;
- the crossbeams are made of profiles UPN coupled through welding of plates with a distance of 2.0 metres;
- the plates for tensioning are welding to the crossbeams with variable dimension;
- the uprights are welding to the tables of load distribution thanks to the pressure from strands in tension.

The steel grid presents an average reversibility due to the numerous welding connections, requiring at the moment of the disassembly the execution of a cut of the profile in correspondence of the welding points, with the exception of the coupling points of the crossbeams as it results more convenient to reuse them in a welding form. Taking into account the grid made with wooden uprights and crossbeams present on the side of Vittorio Emanuele Street, we identify the follow modalities of connection:

- the uprights are placed on the ground;
- the vertical uprights are joint through U steel elements bolted with a variable distance between 6.0 and 8.0 metres;
- the steel plates for tensioning are made integral with vertical uprights through the pressure from strands in tension;
- the crossbeams are joined in a horisontal way through steel U elements bolted with variable distance between 5.0 and 6.0 metres, the crossbeams are made

Fig. 10 _ Connection between uprights and crossbeams by bolting. High reversibility.
Connection between uprights and crossbeams by welding. Low reversibility.

Fig. 11 _ Connection between steel grid and steel plates by welding. Low reversibility.

Fig. 12 _ Connection between uprights and crossbeams through U steel bolted elements-
High reversibility.

Fig. 13 _Corner. Rusting degree R4-R5

Fig. 14 _ Uprights- Rusting degree R0-R2
Crossbeams- Rusting degree R3

Fig. 15 _ Final part of crossbeams-
Rusting degree R4

with spaced and coupled elements through joint insertion of wooden wedges;
- the crossbeams and uprights are securely fastened by the pressure exerted by strands in tension;
- the crossbeams are anchored by steel L brackets, screw down the plates of load distribution;
- the tables for load distribution are made integral to the masonry through expansion bolts.

The wood grid, thanks to the used connections, present a high reversibility.
In the corner point of the building between Vittoro Emanuele Street and Bominiaco Street, the connection between the steel grid system and the wood grid system is made through the welding to the steel plate, which has the function of retaining member of the wood system, of another steel plate to which are also welded the crossbeams that are part of the steel grid system, with negative consequences for the reusability of the corner elements.
The interventions of support structures of the openings, being made of wooden elements, present connections for screwing or nailing and, therefore, reversible. In a similar way, the reversibility of the hoopings made with polyester bands is ensured with the presence of ratchets. Also, the safety intervention of the cover made with tube-clamp systems, corrugated sheets and the safety intervention of vaults, arches and floors made by telescopic props jointed through orthogonal joints with tubes or by stiffing castles and shoring in tubes-clamps are highly reversible.
The limit of the reuse of the element that constituted the stiffing castles is the width of the same equal to 50 cm.
The qualitative analysis of deterioration[20] allows the identification, at work, of the portion of material that do not present residual performances sufficient to its reuse, according to the necessity to effect assessments more specific after the disassembly of the safety systems.
The materials that have been used within the building present sufficient residual performances as they have not been subject to the action of atmospheric events and their own characteristics of durability of the materials exceed the number of years since their installation. It deals with, in fact, the tube-clamp system and with telescopic props that have an average durability equal to 60 years and wooden tables used for the load distribution that have an average durability equal to 40 years[21]. Therefore, the analysis is focused on the materials used on the exterior of the building and presenting forms of degradation caused by atmospheric agents.
The steel profiles UPN and HEA, that constituted the structural grid, are protected through paint. Comparing the profiles surface with the reference examples provided by the legislation, there is a variable degree of rusting. The corrosion does not occur in a generalised and uniform way, but in a localised and discontinuous way. The preventive assessment refers, therefore, to an average value of the deterioration of rusting, postponing the specific identification to the definitive phase of assessment. The HEA profiles, which have the functions of uprights, present a degree of rusting variable between R0 and R1 with worsening to R2 in correspondence of the corners, the welding edges present in the majority of cases, a degree equal to

R3, so as the brackets and L anchoring.
The crossbeams formed by UPN coupled profiles, present a degree of rusting equal to R3. The points of welding with the plates, the final part of the profiles and the corner points present a degree of rusting equal to R4, up to arrive in little portions to a degree R5 with the total detachment of the paint. Such differences in the corrosion level between the uprights and crossbeams can be attributed to the positioning of the elements that are protected by the protrusion of the cover, but above all to the fact that the stagnation of water is facilitated by the horisontalness of the elements and by the form of the profiles, as the UPN are coupled along the web and one of the two elements UPN is always placed with the cavity upwards. Through the visual analysis, there are not significant phenomena of blistering, cracking and flaking.
In function of the identified degree of rusting, it is possible to establish the residual durability, underlining that further and more specific analysis must be carried out later to the disassembly, for what concerns the analysis of the sides not visible and the verifications of shape tolerances.
In case of a corrosion level up to R2, i.e. in the case of the HEA uprights, the painting preserves a residual durability. Hypothesizing a reuse in similar environmental conditions, i.e. considering a corrosivity category C3 (which it is the maximum degree of durability of the paint established by the standard[23] from which the first service of maintenance must be made) the remaining time for the paint arrivals to the degree of rusting R3 is of 6 years[24]. If, instead, the elements are used within unheated places (corrosivity category C2), the remaining time for the paint arrivals to the degree of rusting R3 would be equal to 12 years[25]. Otherwise, the degree of rusting R3 is considered the maximum limit for the durability of painting, so for UPN crossbeams, we will have to consider a residual durability equal to the steel not protected by paint. If the UPN profiles were used in similar current environmental conditions C3, the durability would be equal to 3 years, while in category C2 equal to 6 years. For the purpose of a temporary use, to carry out reconditioning interventions will not be convenient, as further described in detail.
For what concerns the wooden grid, it must be distinguished between the forms of physical deterioration and biological deterioration. From a physical point of view, it detects the presence of cracks and discoloration. The uprights present a lower deterioration than the crossbeams, although, they are more distant from the façade and are less protected from the ledge of the roof. The vertical position favours the flow of the rainwater. Otherwise, the crossbeams present a greater deterioration due to the horisontal position that favours the stagnation and the penetration of the water within the elements. The use of square elements with pith included generates the presence of shrinkage cracks on all sides of the element, factors that facilitate the penetration of water. If sawed, the rectangular elements, not including the pith, have been used, to limit the deterioration through the positioning of the part less subject to the cracks and concave to the rain will be possible.
For what concerns the crossbeams, when they are posi-

Fig. 16 _Discoloration of the elements


Fig. 17 _ Variation of discoloration in function of exposure to sun and rain and constructive positioning


Fig. 18 _ Level of corrosion D of a bracket that has not been protected with paint

Fig. 19 _ Degradation with fissuring of the uprights, chromatic alteration of the terminal part of the crossbeams

Fig. 20 _ Connectionof uprights and crossbeams and radial fissuring of the elements

Fig. 21 _ Attack animal of uprights in the point of contact to the ground

tioned in a coupled way, a greater deterioration of the upper element is found, particularly evident on the sides and on the upper part of the same. The lower crossbeam, instead, is degraded on the sides.

It is found, also, a different deterioration of the elements according to the sunshine of the façade, correlated with both the exposure southeast of the same and with the relationship of the width of the street and the height of the buildings on the opposite front.

If, on one side, major sunshine limits the deterioration caused by moisture, on the others side, the variation of the dimensions and percentage of moisture caused by variation of temperatures generates major cracks on the elements. In fact, higher deterioration is found for cracks of the elements more subject to sunshine and a greater deterioration for moisture (although not yet critical for rot) of the elements subjected to less sunshine; the high moisture of the surfaces (>30%) generates the development of staining fungi that causes the browning of the wood, despite not having influence on the mechanic characteristics. Such speed is attributable not only to the position of the elements from the front of the building, but also to the constructive position. In the joint point between the vertical and horisontal elements, the crossbeams are in most cases subjected to deterioration from moisture, in fact, due to their position between the wall of the building and the wood uprights, the connection point is constructively in a shadow position and it is subjected to water stagnation. In addition, the joint points are subjected to deterioration with fissures because the bond generated by the connection limits the dimensional variations resulting in fissures along the grain of the elements in the surrounding areas to the connection element. On a same element, areas with variable discolouration are found, caused by the combination of differential exposure of the element in its parts to the sun and rain.

The uprights in the part in contact with the ground present signs of biological deterioration, such as the presence of holes caused by animals. On the uprights, the same exit holes are found to also be in correspondence of the wanes, particularly widespread when the bark is present.

The steel components (the contrast plates, the brackets, and the U profiles of anchoring) in the safety system are constituted by uprights and wooden crossbeams that are protected by painting, likely made directly in operation. The painting has done its job of protection and the elements have a low degree of rusting variable between R0 and R2.

Some components were not painted (probably forgetfulness) and present a high level of corrosion, such as level D. This case proves that the protection from corrosion performed by painting, galvanising or mixed systems, involves a substantial increase of steel durability.

In the external part of steel strands, a light deterioration for corrosion is found.

The wooden elements used for support structures of the openings are in a good state, as they do have not have evident signs of physical or biological deterioration. The positioning within the rooms window and doorways, protecting them from weather, has increased the durability.

The nails used for the connection, instead, are sometimes rusty. These nails cannot be reused. In fact, if we proceed to disassembly by extraction of nails, they are for the most part inflected, if, instead, we proceed to disassembly by the cut of the point of connection, they remain fixed inside the wooden element or are cut.
Finally, the polyester bands result in a good state and do not present particular signs of deterioration[26], even if steel shaped elements and wooden tables protected the corner of the load-bearing walls, after the disassembly, it is important to check the integrity of the bands in the contacting points with the corners.

The Civic Museum of Santa Maria dei Raccomandati: disassembly and optimisation of the reuse

The definition of the disassembly modality occurs taking into account the safety systems by type. They are not taken into account the disassembly phases according to their chronological order, they will depend on the type of interventions identified for the recovery of the building, but the disassembly modality is defined in each system in function of the reversibility of connections and of the deterioration of the elements.
We consider the non-use of the elements due to the deterioration, the damaged product during the disassembly operations, the geometric characteristics and the small size consequent to it. Consider, for example, in cases of interventions of support system of the openings to the necessity to eliminate the wooden part.
The modalities and the disassembly phases are defined in function of the used system, as described below.

- Tie-rods with steel grid _

The disassembly happens from top to the bottom, starting from the farthest layer from the wall until it gets to the nearest layer. After removing the chains, the disassembly of the bolted plates to crossbeams is made. After, the crossbeams are cut in the welding points with the uprights. The plates for tensioning are left welded to the crossbeams. In the same way, the crossbeams are removed in a coupled way, and, in this form, will be subsequently reused. The disassembly of the uprights provides that the profiles are cut in correspondence of the welding with the crossbeams, including in the cut part with the L bracket welded on it. It is possible to proceed to the removing of the retaining members' fixtures to the wall and to the removing of the bolted tiles that combine the uprights. After the demolition of the anchoring through concrete of the profiles to the ground and the cut for a length of 50 cm of the profiles adjacent to it are made. Progressively to the disassembly of the uprights, it is possible to proceed to the disassembly of the wooden tables of load-sharing, eliminating the boards in contact with the ground for a length of 50 cm. The wooden tables are arranged in adherence between the walls of the building and the uprights, pausing in correspondence of the connections between the uprights to leave space for the plates of anchoring.

- Tie-rods with wooden grid _

The disassembly happens from top to the bottom starting from the farther layer from the wall until to get to the nearest layer. It is necessary to proceed to the decrease of the tensioning of steel strands and to the remove of retaining plates. After, it is possible to disassemble the uprights that are connected together in vertical by C elements in bolted steel and maintain in adherence to the building, thanks to the pressure exercised by the rods. The parts of uprights in contact with the ground, due to their deterioration, do not present sufficient characteristics to reuse. Therefore, the cut of the same for a length equal to 1 metre above the ground is made. Also, the uprights to contact with the decking of the balcony are cut for a length equal to 0.50 m by the same. Then the crossbeams are dismantled, joined by steel brackets bolted to wooden tables in adherence to the wall of the building and joined horisontally between them by C bolted elements of steel sheet. Finally, it is possible to proceed to disassembly of the boards placed in contact with the wall and connected to it via mechanical elements. The wooden parts affected by connections through elements in C steel sheet are considered not reusable due to the large number of dowels inserted (6 dowels for each side with a space of 25 cm). Otherwise, the parts affected by the connection with L brackets that are composed of only two screws not considered degraded.

- Systems with telescopic props _

At first the disassembly of the "innocenti" tubes connected to props through orthogonal joints is made and after it is possible to remove the pops and wood tables of load distribution.

Fig. 22 _ Dismantling the steel grid

- Coverage _

At first the disassembly of the corrugate steel coverage is made and, after, it is possible to remove below the castle of stiffening in tube-clamp system, with progression from the top to the basis.

- Hooping with polyester bands_

The dismantling of the hoopings performed with polyester bands is easy. The opening of the ratchet lever eliminates the tension of the polyester band. The latter is separated from the ratchet through simple extraction. After, it is possible to disassemble the angular steel and the wood tables.

- Support systems of the openings _

The support systems of the openings are constituted by wooden elements joined by nailing. The disassembly happens alternately through the extraction of nails or is cut off from the concerning part at the connection, such as the wooden part or, when it is possible, the nail exclusively.
In both cases, the wood part neighbouring to the connection undergoes damage. Otherwise, in such an assessment we consider the non reusable part of element neighbouring to the connection points for a length of 10 cm. In case of a support system of doors, we consider the elements in contact with the ground for a length equal to 50 cm unreusable.

For each element that constitutes the safety system, the size and the deterioration level according to qualitative and generic categories (high, medium, high) are defined. So it is possible to have a schedule of reusable elements available[27]. This analysis ends the phase of preventive assessment that allowed us to identify the reusable elements and their geometric and dimensional characteristics and the level of deterioration. For what concerns the definitive assessment, reiterating that it should be done after the disassembly of the elements with available data and information, it is possible to hypothesise plausible scenarios of reuse, in function of the geometric and dimensional characteristic of the elements. At first, it is necessary to identify the elements that are available that have characteristics for a structural reuse.
In the case study, the available steel elements such as HEA 200 profiles, UPN 180 coupled profiles, plates, strands ϕ 22, tubes-clamps and telescopic props born with structural function. The dimensional deviation of the HEA and UPN profiles do not need to be verified as the elements have been already put on the market and their use caused no changes in this sense, the tolerances of mass depend on the level of corrosion, but there were not critical cases that prevented reuse.
With the shape tolerances, by analysing the positioning of the elements in the building, it is found that it must be verified the arching of the web and the error of straightening on the plan of the web for the UPN profiles and the out square and the symmetry of the HEA profiles. Therefore, the structural reuse is conditioned by the results of these controls.

It is considered appropriate to reuse the elements of the tube-clamp system for the definition of site services where the duration of the work provided is preferably comprised within 2 years, in order to enhance the rapidity of assembly/disassembly of such constructive system. At the current state, these elements have zero deterioration; therefore, they can be reused without treatments.
Otherwise, it is considered appropriate to use the profiles UPN, HEA and the plates for the definition of the bearing structure (hypothesizing satisfied the verifications of shape tolerances) of site services where the duration of works is more than 2 years. If on one side, in fact, the time of assembly/disassembly are greater, on the other side these systems allow the construction of structures of greater size and able to withstand a higher load (with structure in beams and pillars) as well as presenting greater durability.
The durability is not due to the material, which in both cases is steel, but it is due to the positioning of the bearing structure compared to the constructive element. The tube-clamp systems, in the reuse to the construction of site services, are placed outside of the closure and, consequently, more subject to the damage caused by atmospheric agents, compared to the UPN or HEA profiles that instead are situated within the closure.
The choice to direct a system towards the temporary works of short duration and the other system towards temporary works of medium duration it is carried out with the aim to enhance the performance of the systems to direct the same towards the uses that have a greater degree of compatibility. This choice is possible thanks to the wide availability of the components of both systems. Otherwise, the systems may be used indifferently.
In cases in which the UPN, HEA profiles, the plates and the brackets are used for temporary structures, it is considered appropriate to ensure a durability of more than 15 years in addition to the life cycle of using for safety.
The HEA profiles with a rusting degree Ri 0 or Ri 1 can be reused without suffering treatments of reconditioning. Considering, in fact, a reuse in environmental conditions C2 (to unheated internal) and a linear increase of the corrosion level, the elements ensure a durability sufficient for the destination of hypothesized use. When a degree of localized rusting equal to Ri 2 is present, in function of durability of each of the expected life cycles, considering an overall durability of 15 years, it is possible to choose between two different scenarios of intervention.
The first consists to put in operation the element without treatments, the rusting degree will arrive to Ri 3 in 12 years and, therefore, proper intervention of reconditioning must be done. One of the cycles of disassembly of the building structure will have to coincide with the achievement of such levels, before the next assembly a secondary pre- treatment for localized mechanical abrasion (degree of preparation P MA) will have to be made. After the appropriate verifications, a new coat of paint is applied that, in consideration of the overall durability (15 years), must be chosen between the indicated types according to the legislation with low durability including between 2 and 5 years[28].

The secondary scenarios of intervention consists in carrying out interventions of reconditioning before starting work on the element with the aim to restore a degree of rusting to Ri 0, such that it can ensure a sufficient durability without treatments between the various life cycles. In such cases, a secondary pre-treatment localized with manual or mechanical cleaning (degree of preparation P St 2) may be carried out and after the appropriate verifications, a new coat of paint can be applied, that, in consideration of the overall durability (15 years) must be chosen between the indicated types according to the legislation with average durability including between 5 and 15 years. In both cases, the treatments can be performed on the construction site.
The UPN coupled profiles and the plates of anchoring present a general degree of rusting equal to Ri 3 and a degree equal to Ri 4 in the welding points. They must undergo interventions of reconditioning before being reused. It is possible to carry out a secondary preventive treatment of blasting with compressed air and with pressurized liquid on the construction site (degree of preparation Sa 21/2). After, the assessment of the roughness of the surface substrate may be carried out on site and a painting operation with average durability from 5 to 15 years, considering a class of environmental corrosivity C2 (unheated internal). It is considered appropriate to use such a kind of painting, considering the temporary nature of the reuse; the assembly/disassembly of the element during its life allows, in fact, to easily monitor the deterioration and eventually to carry out maintenance operations. In all cases, working with the paint on surfaces already painted, it is considered appropriate to carry out an assessment of compatibility of the paint that is punctually applied, with the aim to ensure a uniform durability to the element.

From the carried out analysis, it is evident the opportunity of reusing within the same building structure, as possible, elements that, before reusing, have the same level of corrosion, with the aim to maximize the residual performance. The use in the same building structure of elements with different level of deterioration requires uniform the treatments, according to the worst level.

Consider, for example, the reuse of elements with a rusting degree equal to Ri 1 and to element with a rusting degree Ri 3. All the elements must be treated as though they had a level of corrosion equal to Ri 3 to act simultaneously for the maintenance. Such considerations find an exception in the case of definition of temporary structures.

Consider, for example, the reuse in the same structure of elements coming from the selective demolition of the safety system of the Civic Museum di Santa Maria dei Raccomandati with rusting degree Ri 1 and Ri 2, assuming that they are treated with painting of medium duration. Hypothesising a reuse in the same conditions, both elements present a sufficient durability for the construction of a temporary building structure with a normal life equal to 5 years.

At the moment of the disassembly, the same elements that before installation presented a rusting degree equal to Ri 2 have reached a degree equal to Ri 3, while the element that before installation presented a rusting degree equal to Ri 1 have reached a degree equal to Ri 2 and present a residual durability of another 4 years, before reaching of the degree Ri 3 in the same environmental conditions. Therefore, the temporariness of the system facilitates the reuse of elements with different deterioration, thanks to the possibility to carry out treatments of reconditioning, during the cycles of disassembly that happen in a limited period. Differently, in cases of stable architecture, it is important to use elements that present the same level of deterioration with the aim to optimise maintenance interventions. If the steel elements do not fulfil the requirements for a structural reuse, they may be used for not structural functions. Consider, for example, the definition of dividing walls, decking or air space for technical implants in recovery interventions and in temporary structures.

Although this use is not consistent with the original nature of the elements that are born for a structural use, it represents a modality of optimisation for the environmental impact caused by its production. The no structural reuse has less stringent conditions on the range of tolerance of corrosion of the elements, such as the choice in performing treatments has repercussions almost exclusively aesthetic or dangerous for human health due to the presence of rust, having the element unresponsive to its functions only when the corrosion affected the internal cohesion of material. Hypothesising a not structural reuse within the building structure (corrosivity category C2), the condition in which the element is not responsive to its function due to the lost of cohesion of the material occurs in a period of time far exceeding the nominal life of an ordinary structure as established by the legislation (Vn>50 years).

For example, supposing a non-structural reuse of a UPN 180 profile in steel with a low carbon content with length equal to 1 metre in corrosivity category equal to C2, with an annual mass loss equal to 200 g/sqm, after 50 years from installation, a lost of mass equal to 27% is found. Therefore, the structural profile has a proportional reduction of its bearing capacity.

Hypothesising a uniform progression of the corrosion, the 180 UPN profiles, after 50 years present a bearing capacity comparable one of a 140 UPN profile[29].

Therefore, the original nature of the profiles that are born for a structural use produces an oversizing of the performance, in the moment in which they are reused for a not structural aim, increasing the tolerance range of the corrosion level.

The telescopic props can be used according to their original function, such as for formwork and the casting of slabs with wet technologies (reinforced concrete), for shoring of armatures in excavation or retaining wall or other uses of shorings. In cases of temporary reuse, the durability is defined by the type of system of adopted protection (painting, galvanizing or special systems).

The tube-clamp systems can be reused with temporary function, such as with scaffold function or for definition of temporary sites services. In this latter case, the elements, if they have a structural function, must be assessed considering the used material and the type of surface treatment defined, such as they must be structurally considered as steel tubular profiles. If, instead, they are used in definitive interventions with not structural function (for example, for the definition of flexible interior partitions) for them the same considerations outlined above for the steel profiles are valid.

In the reuse it is necessary to carry out the structural calculations taking into account the type of used steel, the length and the class of belonging (classes A, B, C, D and E)[30], that consequently determine the nominal characteristic resistance. Dealing with reuse, the structural space will be determined by the kind of available props. Each prop, according to the legislation, in fact, has to be marked with the indication of the manufacturer, the year of construction, the classificatio and the quality control adopted. In the present case study, the telescopic props and the tubes and clamps having been used within the building do not present signs of corrosion. Therefore, they may be reused without prior operations of reconditioning, but, making an analysis on the preventive treatment and programming, respect to it, a maintenance inspection. In function of the deterioration level and of the residual life of the building, it is possible to identify the preventive treatments to apply and to plan future maintenance. In a similar way, the temporary use of elements whose nature is related to definitive usages could limit the exploitation of the residual performance.

For that which concerns the wooden structural elements in the technical report attached to the safety project of the Civic Museum of Santa Maria dei Raccomandati the use of "wood of 2° category, not resinous, allowable stress: σamm = 102 kg/cmq" is indicated, without giving further information. This indication is according to the Regulations DIN 1052/88 and 96 based on the calculation with method of allowable tensions, that to date, results passed at a European level. In fact, the European standard EN 14081 "Timber structures - Strength graded structural timber with rectangular cross section" imposes the marking CE of wooden elements with a rectangular cross section with the indications of specific characteristics including the resistance class, accordingly established by the standard EN 338 "Structural timber – Strengh classes". The structural reuse of wooden elements will not, regardless of the definition of the same resistance class.

When information about the resistance class of the elements before their first life cycle are available, thanks to the technicians documents or thanks to the presence of the marking CE (that it is not cut in installation), it will be necessary to verify by visual grading the possible variation only of some defects that could cause a change in the resistant class, such as the fissures, the deterioration by fungi or insects and deformations (bow, crook, twist and cup). Otherwise, when sufficient information are not available, as in the case study, the visual grading will need to be made *ex novo*, with the aim to identify the characteristic values of the elements.

The technique relation describes only the belonging to the hardwood timber, therefore, the visual grading can be carried out according to the parametres indicated in the specific prospectus (n.4) of the standard UNI 11035-2:2010 "Legno strutturale. Classificazione a vista dei legnami secondo la resistenza meccanica. Parte 2: Regole per la classificazione a vista secondo la resistenza meccanica e valori caratteristici per tipi di legname strutturale" (Structural timber. Visual strength grading for structural timbers. Part 2: Visual strength grading rules and characteristics values for structural timber population) and then, once the species is identified, it is possible to identify the resistant category. The Italian legislation identifies, in fact, only one visual category for hardwood (category S), to which corresponds different resistant categories in function of the species. In the present case, some of the vertical elements correspond to the legislative definition of "Uso Fiume"; for them the Italian standard UNI 11035-3:2010 "Legno strutturale. Classificazione a vista dei legnami secondo la resistenza meccanica Parte 3: Travi Uso Fiume e Uso Trieste" (Structural timber. Visual strength grading. Part 3: Timber Uso Fiume and Uso Trieste) although defines the method of measurement of the characteristics and of the defects, do not allow the identification of the resistant category, as at present, it provides only the characteristic values of fir. Therefore, waiting for the implementation of the legislation, these elements can be classified without taking into account the wanes, according to the regulations of proven reliability[31]. In such way, however, the resistance values attributable to these elements are penalized. In the case study, due to the present configuration in the installation of the elements, it was possible to assess in details only the deterioration, assuming a lack of visibility of a side. For wooden elements, being in contact with the ground presents a high risk for biological deterioration (animals and mould) that is cut and is expected to have the degraded part discarded. Instead, the portions in which the presence of widespread attack of insects is found, visible above all in correspondence of the wanes and where the bark is present, before of the structural reuse, if they meet the minimum requirements according to the legislation, they will be treated by curative piloted injections or by application of curative products by roller, brush or spray, when the attack is slight.

When the elements present a slight deterioration widespread with presence of mould and, consequently, discolouration alterations, evident on the upper parts and on the side crosspieces, it is possible to make a surface cleaning by mechanical abrasion and after it is necessary to apply preventive treatments.

Varying the intensity of abrasion, the brushing can be made also to clean the wooden surfaces before the applications of possible treatments to ensure greater effectiveness and to restore the original colour when discoloration alterations are present and we want to get a better aesthetic result. The same treatments must also be made when such deterioration is found on the elements that will not be used for structural aims.

Even if, in such case, the presence of deterioration does not undermine the safety of the building, it generates the decrease of the performance of the element and represents a risk of transmission for the structured elements (dangerous above all, in case of a biological attack).

In any case, before reuse, the moisture of the wood must be measured by capacitance instruments[32] or, when it is possible, through the extraction of a specimen with the size established by the legislation and after calculation with the oven dry method[33]. If the moisture is greater of the 16%, before of the installation, we will have to provide to dry at free or artificial air, up to a moisture equal to about 12% (temperature 20°, environmental relative moisture 65%), with the aim both to reduce the risk of biological attack and to correctly estimate the mechanical property.
In case of structural reuse, if the visual grading identifies the worst defects in knots, wanes, deterioration or fissures, in function of the position or of the intensity of the same, the possibility to cut the part of the element that affect the structural reuse must be assessed or, in case of surface deterioration, proceed with a curative treatment. If the worst defects identified are the rate of growth, the slope of grain, the deformations or the reaction wood or other widespread defects, the wooden elements must be used with not structural function. In the structural reuse, a correspondence between the boundary conditions (moisture and temperature of the environment), the type, the duration and the load modality due to the conformation and of then localisation of the building structure and the defects present in the part of the element most stressed must be identified.
In the case study, with concern to the wooden components, an assessment of the defects and of the deterioration not being possible on the construction site because the safety systems have not yet been disassembled, we hypothesise a structural reuse of the elements based exclusively on the size, i.e. between the materials/components indicated as "reusable elements", we consider structural reusable the components that have a section of 14x18 cm and 20x20 cm with length greater or equal to 2.0 metres and a not structural reuse of the elements that have a section of 14x18 cm and 20x20 cm with lower length to 2.0 metres and of all components with different sections (10x10, 20x5, 15x5 and 15x2.5 cm). From a percentage point of view, the 26.8% of the wooden elements is reused for structural aims and the 73.2% for not structural aims. Both in case of structural reuse and in not structural reuse, it is necessary to identify the class of durability and chose in function of the class of environmental risk.
In the case study, as these are elements for structural use in hardwood and not having at disposition more specific data about the used species, it is carried out the comparison between the operative modalities aimed to optimize the durability in case of alder wood and in case of poplar wood, belonging to the same structural category of visual classification according to the Italian standard.
The alder wood presents a natural class of durability against the fungi attack equal to 5 (not durable). It is not resistant to anobiids and to termites, presents a heartwood with class of impregnability 1 (impregnable) and a sapwood with class of impregnability 1 (impregnable). The poplar wood presents a natural durability class to the fungi attack equal to 5 (not durable); it is not resistant to anobiids, termites and to cerambycidae, it presents a heartwood with class of impregnability 3 (little pregnable) and a sapwood with class of impregnability 1 (impregnable).
If the elements are used within a dry environment (class of use 1), all species can resist the fungi attack without preventive treatments, in a similar way a high risk of insects attack does not exist.
If the elements reused are sheltered of the atmospheric agents, but with possibility of occasional intermittent humidification >20% (class of use 2), both the alder elements and poplar have a sufficient natural durability and do not require preventive treatments, if constructive measures act to decrease the risk of condensation on the elements are used. Only when the elements result inaccessible or are in need of a higher durability than natural, some preventive treatments will be applied. These treatments results are more efficient on alder wood compared to poplar wood, as the latter presents a lower impregnability of heartwood, on the other hand the minor impregnability of the heartwood of the poplar increases the resistance to the fungi attack because it will be less subject to moisture absorption. For what concerns insect attack, the alder elements must be protected from the attack of anobiids and termites, while the poplar elements must be protected from the attack of cembracidae, anobiids and termites, with the use of preserving products that ensure a class of penetration NP1[34]. The verification of retention must be performed on an analytics area equal to 3 mm.
When the elements are used externally and are exposed to humidification (class of use 3), the same considerations made for use in classroom 2 can be applied, with the difference that a greater penetration of the preserving product will be ensured.
Therefore, while in cases of reusing in class of use 2, it will be possible to get a good resistance to fungi and to insects, through treatments with brush, roller or spray performed on site. In cases of reusing in class of use 3, although both the surface treatment and plant treatment at pressure are allowed by the legislation, this latter will ensure a greater penetration of the product.
For the elopements in alder wood, it will be necessary to ensure a penetration level NP3 (6 mm of sapwood on side faces). The verification of retention will performed on an analytics area equal to 6 mm sides, while for the poplar wood it will be necessary to ensure a penetration level NP2 (3 mm of sapwood on side faces and 40 mm of sapwood axial direction) and to perform the verification of retention on an analytics area equal to 3 mm sides.
In a similar way in the case study, the elements for non structural use can be constituted of sawmills wood such as of elements that in the previous life cycle have had a structural function and in the assessment of structural reuse were discharged due to the presence of defects or can be constituted of panels and elements in wood of fir and pine. In case of temporary reuse, the variability of weather conditions as well as of the geographical localization of the building structure (and consequently the variability of the kind of the biological attack) is controlled thanks to the possibility to replace or to treat the elements between the cycles of assembly/disassembly.

Site services in Santa Maria Paganica square: the executive project

The site services were projected by foreseeing the reuse of the components that constituted the safety systems of the Civic Museum of Santa Maria dei Raccomandati, integrated, when not enough, with elements coming from selective demolitions of the reconstruction of nearby sites and with materials of the local supply chain.

The constructive systems are constituted from constructive systems that make reference to those previously projected (as described in paragraph 8.3), modified in function of the geometrical and dimensional characteristics of the available components and of newly projected constructive systems, when the components coming from selective demolitions are an exception compared to most commonly found elements. In particular for the safety system of the Civic Museum of Santa Maria dei Raccomandati, wooden elements with a square section are used and reused with a bearing function.

Even if, in fact, referenced macro-categories have been identified for the elements that constituted the safety systems, the typological and quantitative variability present can stimulate different solutions case by case.

The case study shows that the constructive systems previously described (in paragraph 8.3) represent a reference point to facilitate the reuse of the components by the enterprises and to express potential, but that are not exhaustive compared to the present opportunities.

For each site service illustrated below, it is possible to identify an abacus of components necessary for its realisation (as explained in the "Appendix F"[35]) and to define the percentage[36] of materials that come from the selective demolitions and of the materials produced *ex novo*.

All of the projected services are connected to the electricity grid and they can be covered with photovoltaic panels, aimed at eliminating the heating system.

The spatial choices are strongly conditioned by minimum regulatory requirements and by user's expectations.

The changing room

The constructive system is made with constructive parts CV-1a, COi-1a and COs-1a with variations in the section of wooden elements.

The constructive equipment is constituted of a bearing structure made with wooden bearing walls and horizontal closures with wooden beams (20 x 20 cm) and steel beams (UPN 240); the vertical closures are constituted by planks and wooden elements placed in compliance with passing rods that have a bearing function and are connected with the horizontal closures by steel connectors.

The wooden walls are insulated with sheep wool panels (thickness 10 cm) within and covered with wooden boards. The horizontal closures are made up of wooden boards with interposed sheep wool insulation (thickness 10 cm). The water tightness of the upper horizontal closure is guaranteed by sloping steel corrugated sheet.The foundations are composed of screw piles.

The changing room is equipped with an electrical system. The vertical closures have a transmittance of 0.25 W/ksqm and the horizontal closures equal to 0.20 W/ksqm.

A planimetric space of 3.0 x 5.0 m and an average height of 4.0 m are considered for the construction of the changing room. The necessary elements are as follows: 12.6 mc of wooden elements, 1030 kg of UPN 240 profiles, 32 ml of tie-rods, 290 kg of connectors, 24 sqm of corrugated steel, 6.5 mc of insulation and 4 screw piles.

The 65.9% of materials/components required for the construction of the changing room is derived from the selective demolitions carried out in neighbouring reconstruction sites, while 34.1% consists of new materials, namely insulation, screw piles and connections.

The restrooms

The constructive system is constituted by constructive parts CV-3a, COi- 3a and Cos-3a with variations in the section of the wood elements.

The variation of the inner covering of vertical closures and of the decking and the predisposition of the air space in the lower horizontal closure for the passage of pipes to the water supply and sewer system can be positioned in the existing interspace between the three-dimensional grid of tubes and clamps and the wooden envelope.

The constructive equipment constitutes a bearing structure with tubes and clamps and lower horizontal and vertical closures constituted by wooden plank with interposed insulation of sheep wool.

The upper horizontal closure comprises of two parts: one part formed by double wooden boards with interposed insulation hanging from overhead trusses made with a tube-clamp system and another part above the trusses made with wooden board and corrugated steel sheeting.

The inner covering of the vertical closures is made with polycarbonate panels.

The floor is made with MDF wood. The closures are connected to a tube-clamp structure through eyelet and omega connectors.

Internal partitions consist of a wooden frame coated with polycarbonate panels. The restrooms are equipped with water and electricity.

Vertical and horizontal closures have a transmittance of 0.28 W/ksqm. Considering a planimetric space of 5.3x7.0 m and an average height of 4.50 m, which can accommodate 3 showers, 3 sinks and 3 waters, the following materials are needed for their construction: 5.5 mc of wooden elements, 25 sqm of alveolar polycarbonate panels, 500 ml of tubes, 700 clamps, 35 sqm of corrugated sheet , 32 ml polyester bands, 7.8 mc of sheep wool insulation, 0.2 mc of MDF flooring and 26 kg of steel connectors (eyelets and omega profiles).

The 43.4% of materials/components necessary for the construction of the restrooms comes from selective demolitions carried out in neighbouring reconstruction sites, while 56.6% consists of new materials, namely insulation, flooring, polycarbonate panels and connections.

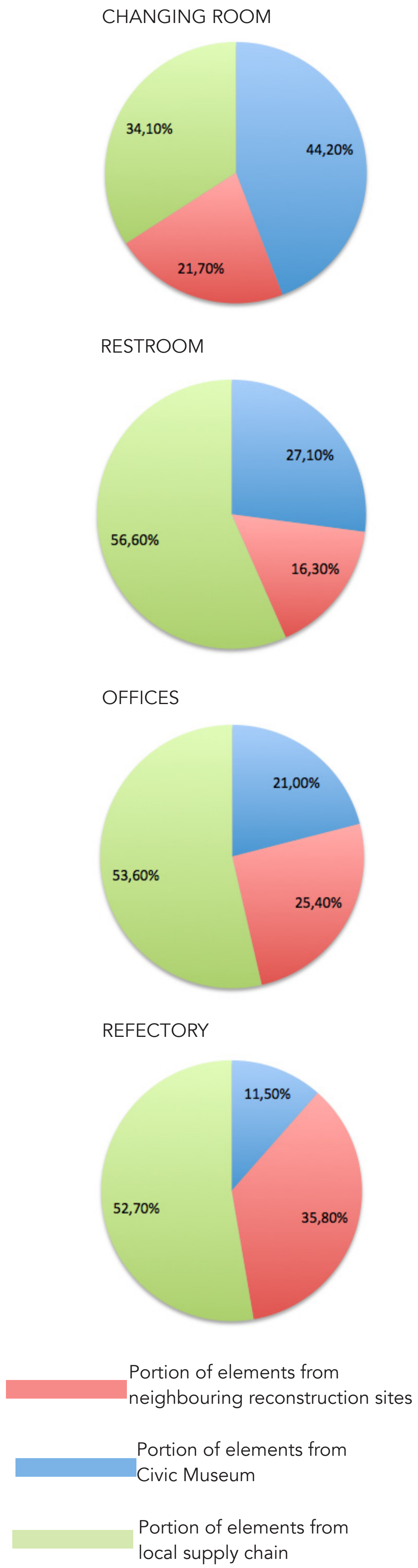
The offices

The constructive system was projected *ex novo* in function of the available elements after the selective demolition of the Civic Museum. The building system contains a bearing structure made with wooden beams and uprights with vertical and horizontal closures formed by wooden boards with interposed insulation (10 cm thickness).
Corrugated steel panels docked on the tables of the upper horizontal closing ensure a watertight seal.
Wooden uprights are anchored by steel connectors in precast concrete plinths. The transmittance of the envelope is equal to 0.30 W/Ksqm.
A planimetric space of 4.0x7.0 m and an average height of 4.30 m, requires 10.5 mc of wooden elements, 38 sqm of corrugated steel, 12 mc of insulation, 190 kg of steel connectors and 0.7 of precast concrete for the construction of the offices.
46.4% of materials/components required for the construction of the offices is derived from the selective demolitions carried out in neighbouring reconstruction sites, while 53.6% is made of new materials, primarily insulation, concrete plinths and connections.

The refectory

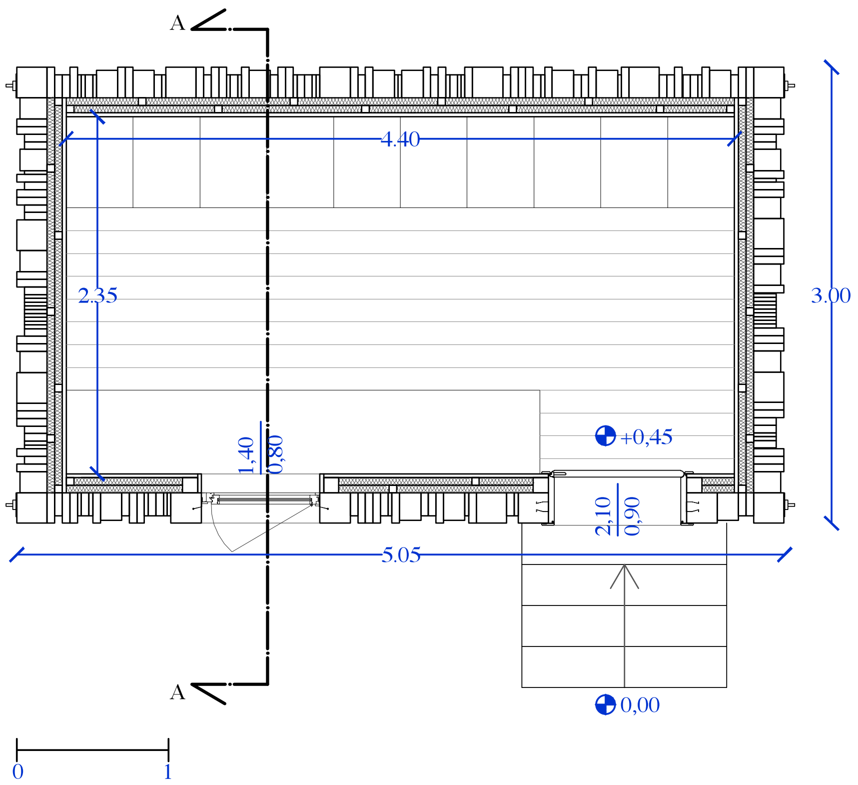
The constructive system is made of constructive parts CV-4a, COi-1a and Cos-4a, with variation of the sections of the steel profiles and wooden elements and of thickness and positioning of insulation.
The construction organisation consists of a bearing structure made with a steel frame with HEA pillars and UPN beams and of horizontal and vertical closures made of wooden boards with interposed sheep wool insulation (thickness 10 cm).
The upper horizontal closure ensures water tightness thanks to corrugated steel in a sloping position anchored below to wooden boards.
Screw piles are used for foundations.
The refectory has an electrical and water supply.
The closures have a transmittance of 0.28 W/ksqm.
A planimetric space of 4.0x10.0 m and an average height of 4.30 m is considered. These necessary materials for the construction of the refectory are as follows: 15.0 mc of wooden elements, 950 kg of HEA 200 profiles, 3800 kg of UPN profiles, 190 ml of polyester bands, 60 sqm of corrugated sheet, 280 kg of steel connectors, 17.5 mc of sheep wool insulation and 6 screw piles.
47.3% of materials/components required for the construction of the refectory is derived from the selective demolitions carried out in neighbouring reconstruction sites, while 52.7% consist of new materials, namely insulation, screw piles and connections.

The executive plans in scale 1:50 of the building structures that can host the functions previously described are presented below: the changing room, the restrooms, the offices and the refectory, that could be made in the common site area.

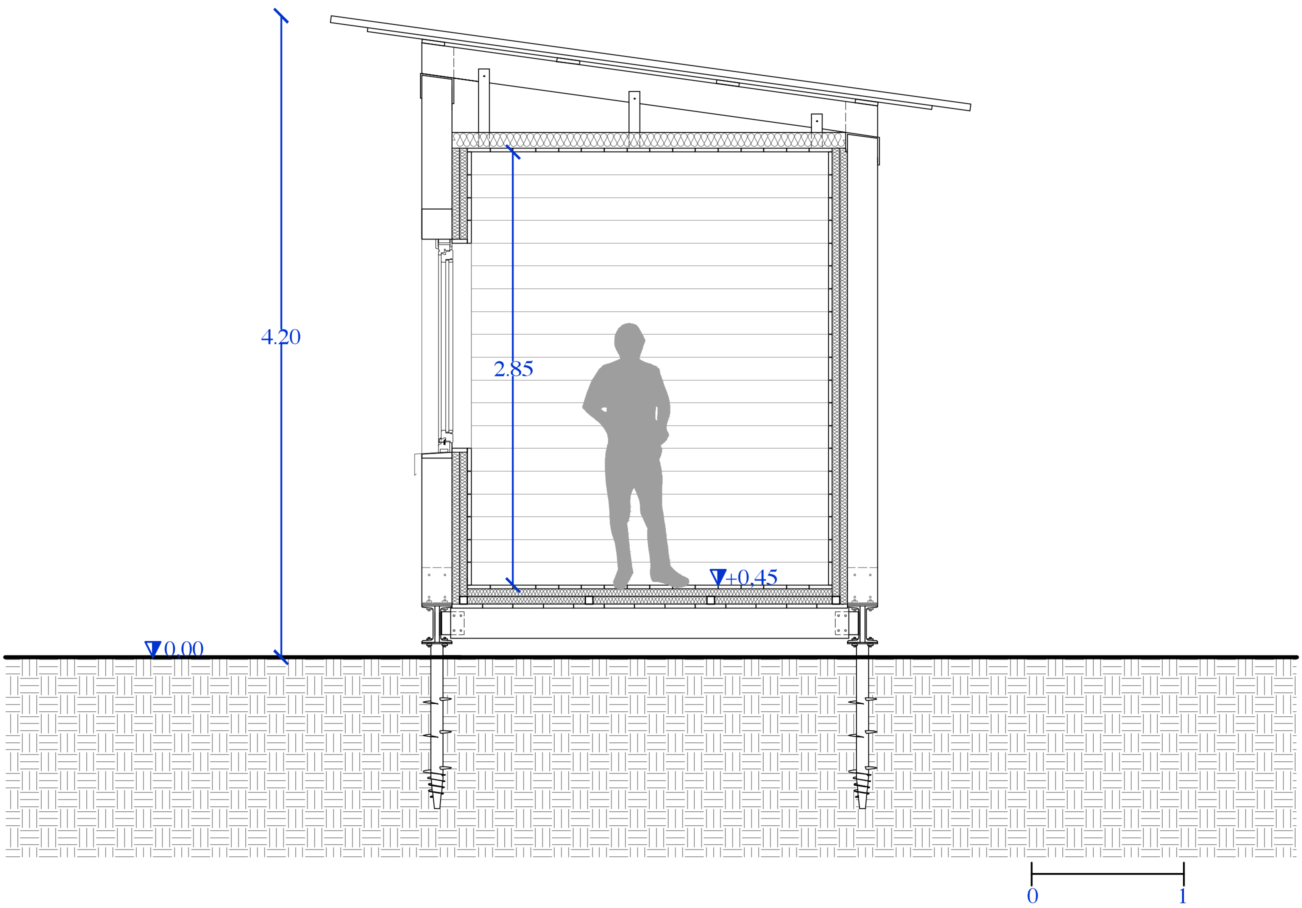


CHANGING ROOM

Plan

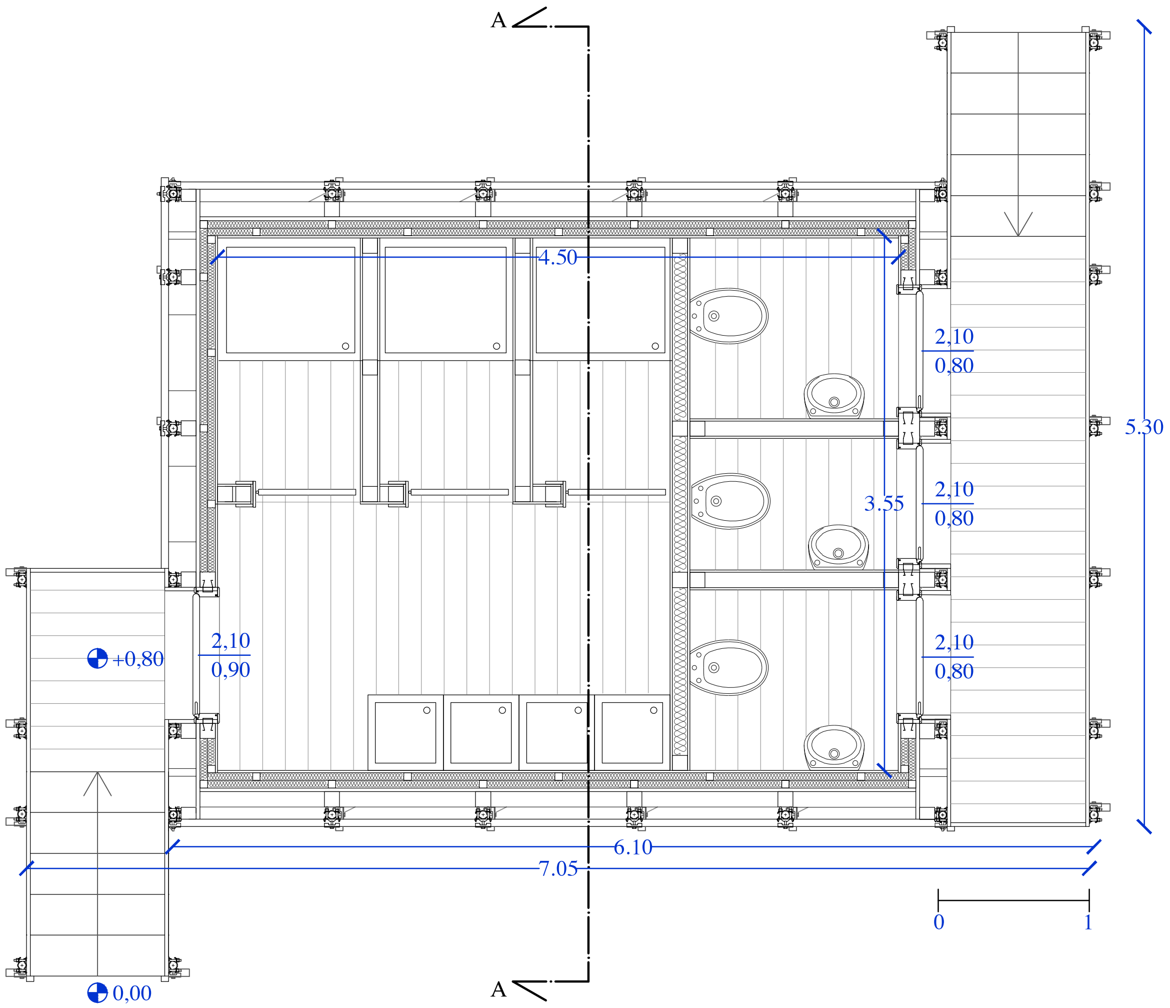


Section

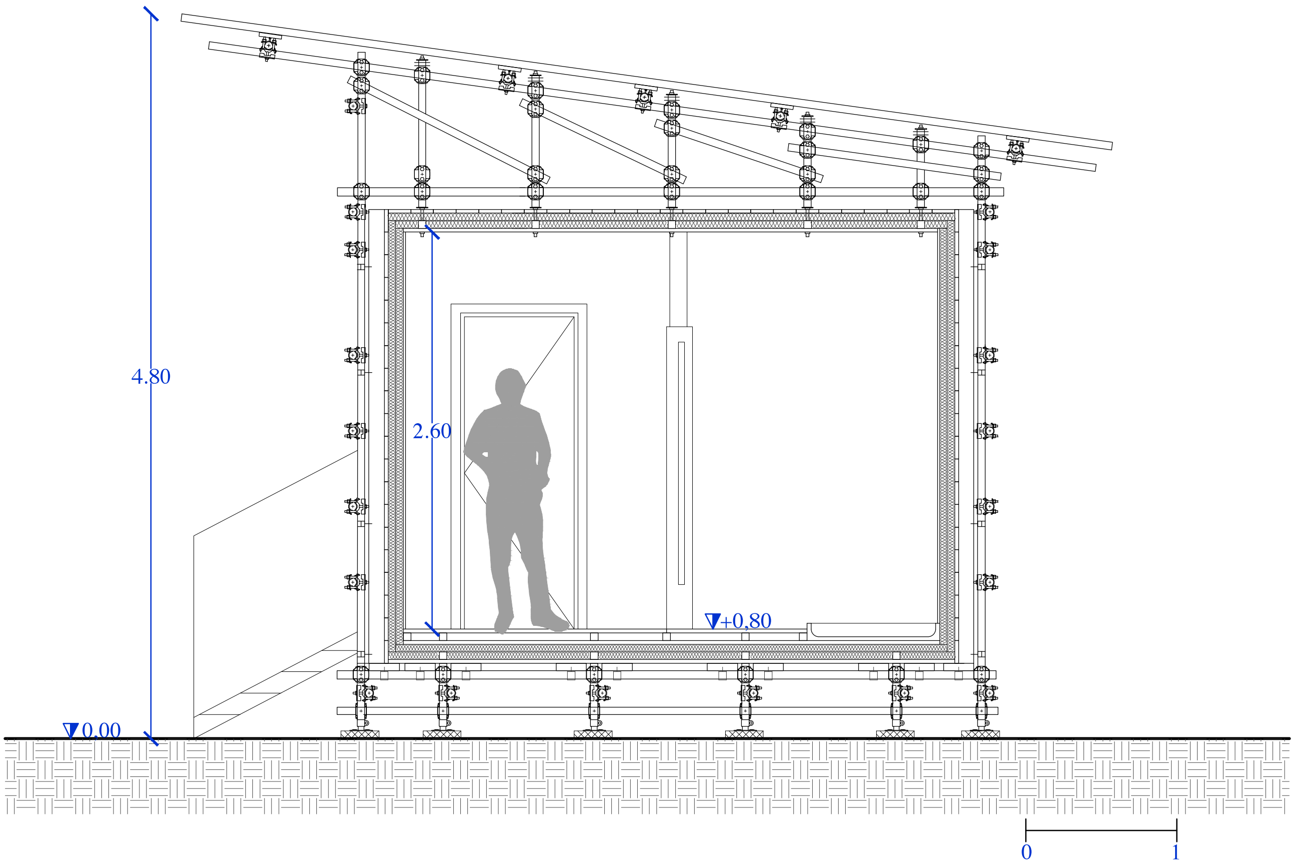


RESTROOM

Plan

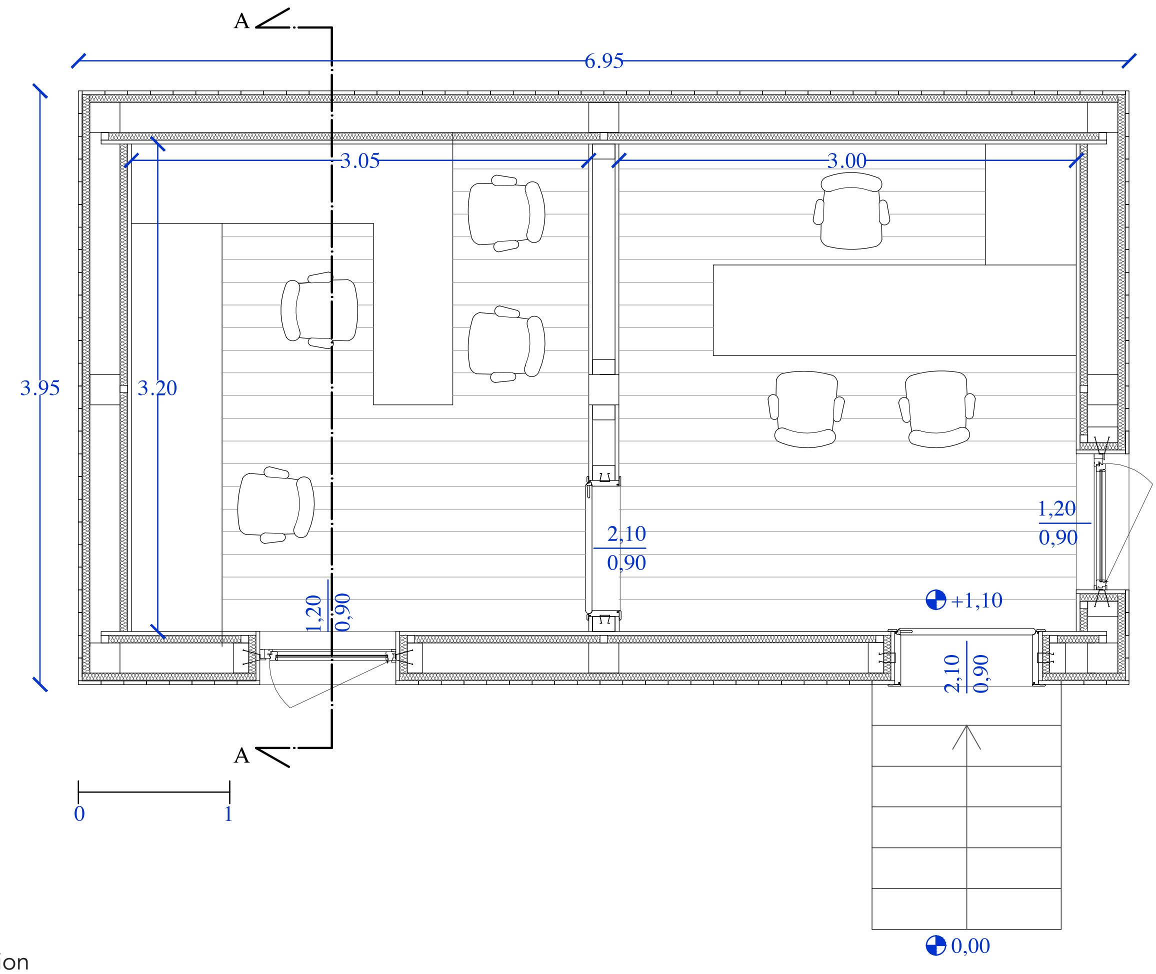


Section

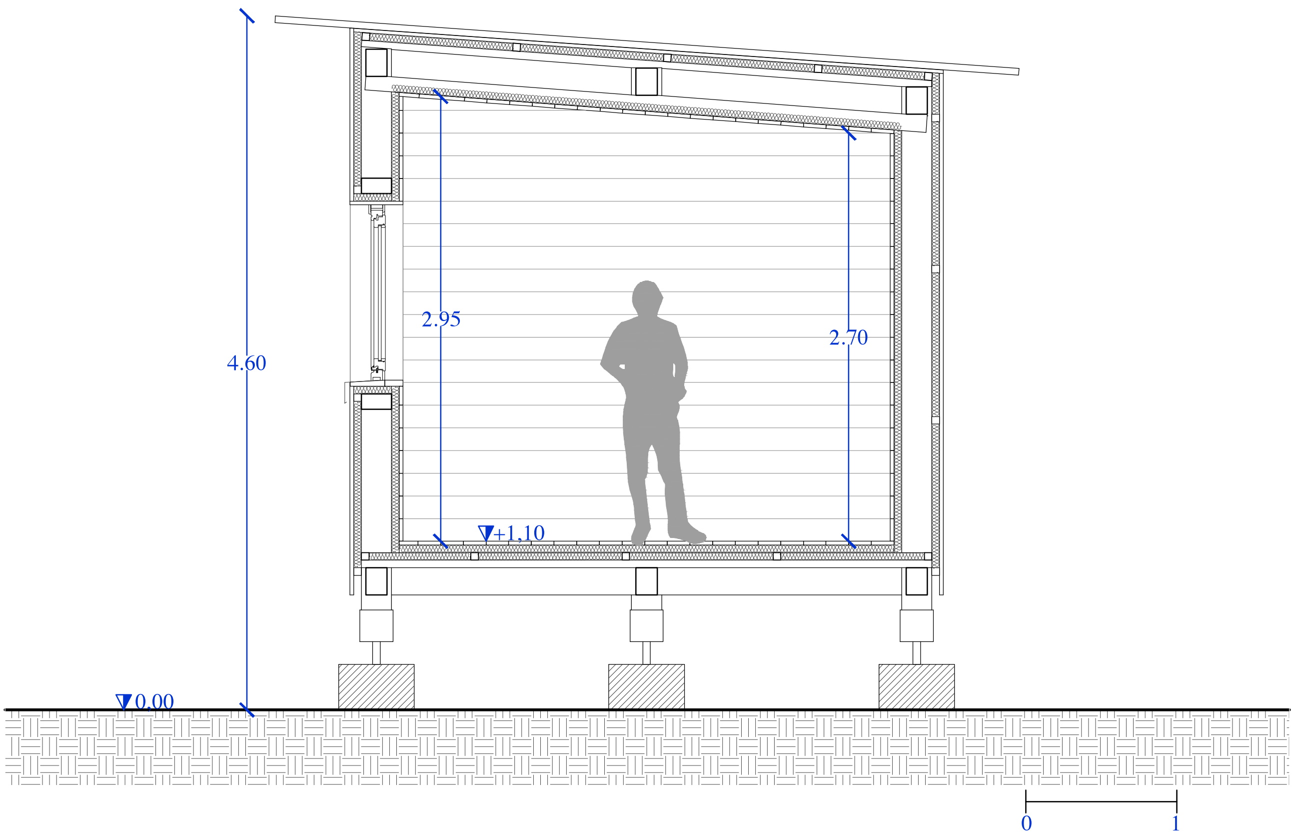


OFFICES

Plan

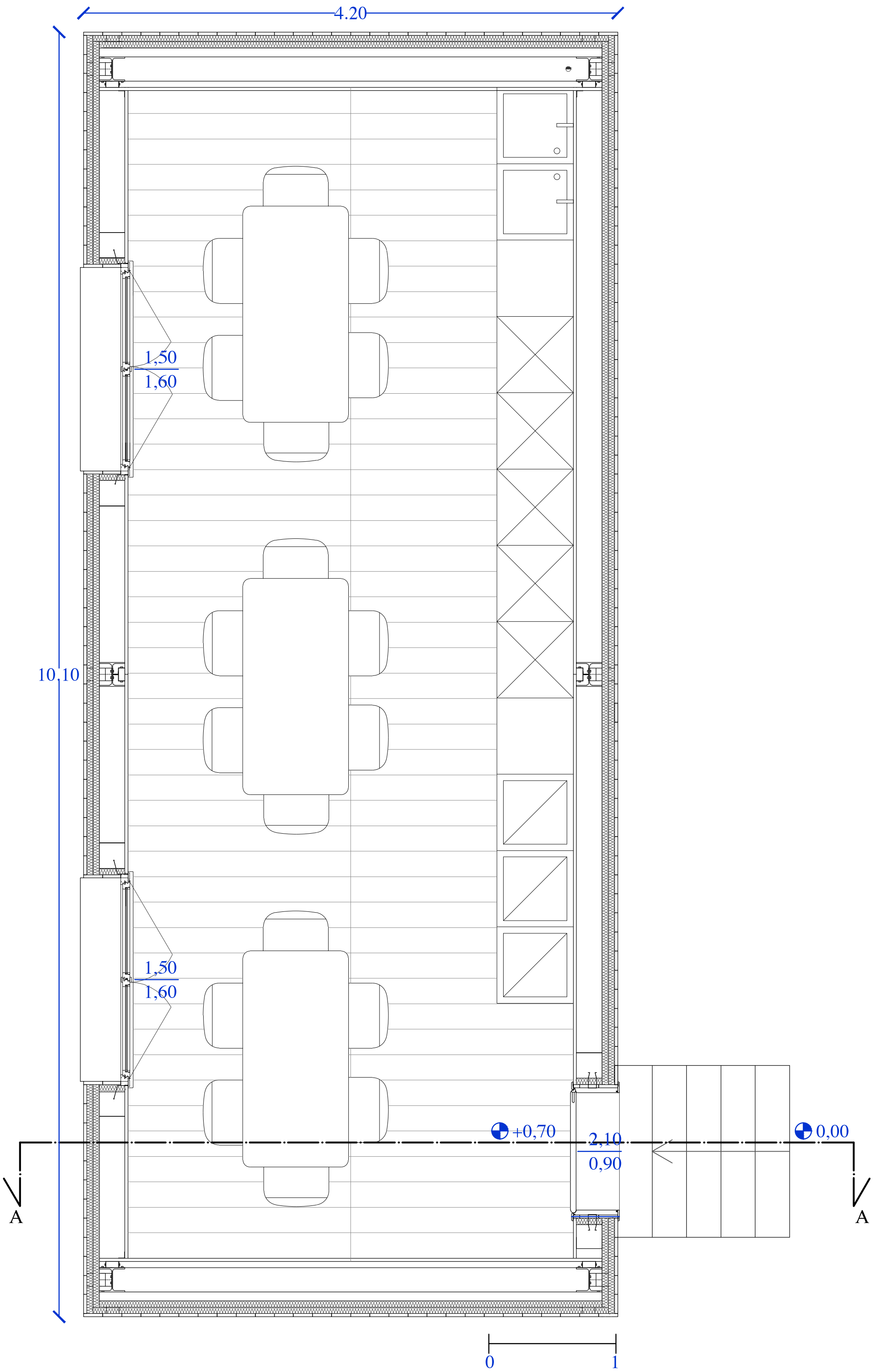


Section

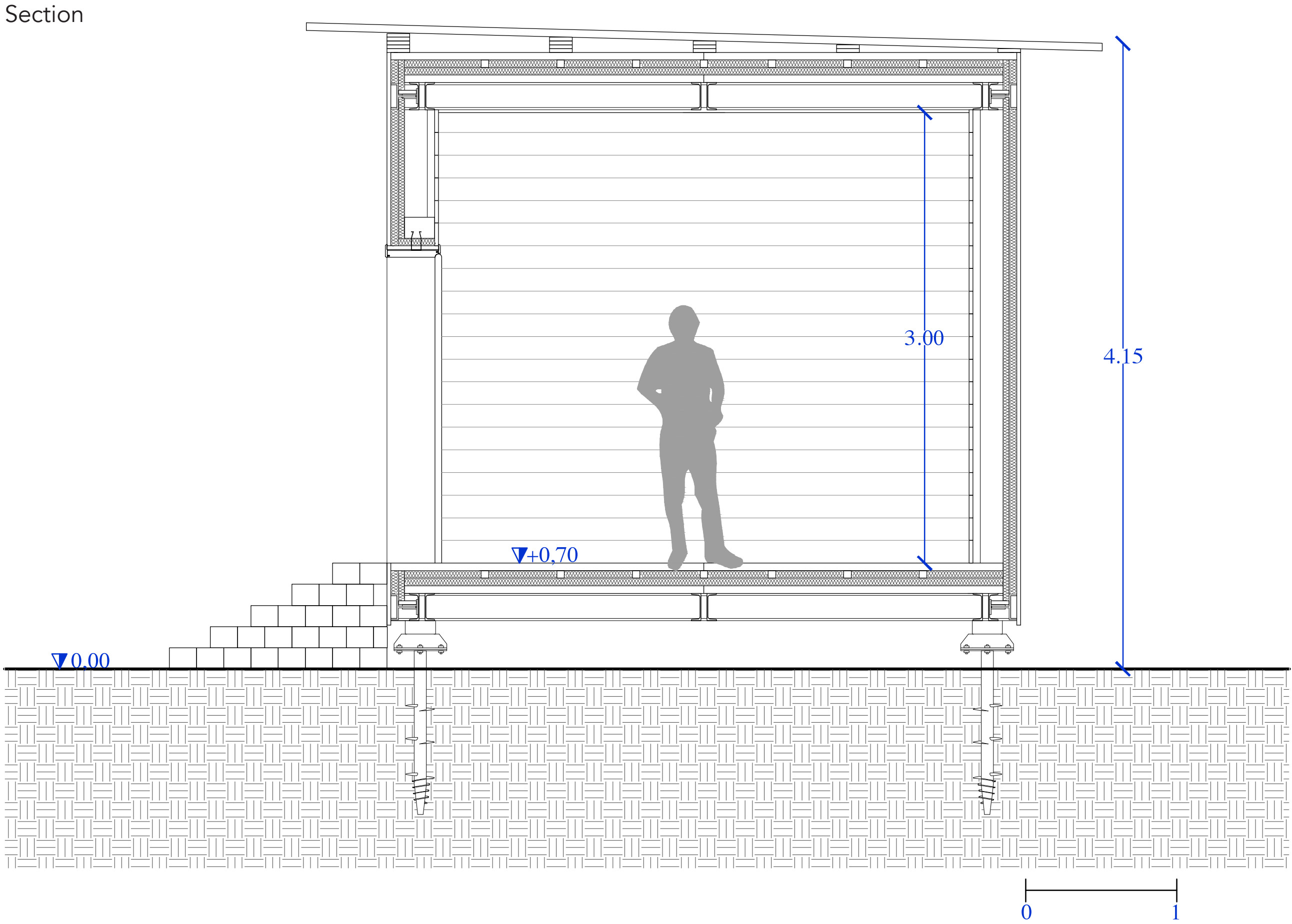


REFECTORY

Plan



Section



Economic convenience

The cost to build the site services reusing the material resulting from selective demolition is equal to the following: new materials, transportation, treatment/adjustment of elements and installation.

The cost of reused materials is considered equal to 0 because, at present, the waste does not have a market value. The cost of new materials/components is equal to approximately 25000 euros. The cost of freight can be overlooked, since, at present, the materials are also transported to temporary storage. The cost of the assembly is equal to about 6000 euros.[37].

The total comes to approximately 31000 euros.

Even if it is necessary to carry out reconditioning treatments or to adapt the components, the cost of these is lessened. This is due to the possibility of reuse for the architectural structure in both the short and long term by simply varying the placement of elements within the building system or by adding additional components.

The cost for the construction using prefabricated modular systems on the market is equal to the cost of the prefabricated blocks, the cost of transport in the pipeline and the cost of transportation of materials not reused for temporary storage. The cost of the prefabrication is equal to about 35000 euros. The cost of transport for these materials to the construction site is equal to about 3000 euros[38].

The cost of the transport to temporarily deposit the materials that are not reused is equal to 1200 euros.

The total is equal to about 39200 euros.

In addition, it should also be considered an economic advantage resulting from the non-occupation of the industrial warehouse that is currently being used as temporary storage. The variability of the housing market in this historical juncture in L'Aquila makes this assessment unlikely. Therefore, it is neglected. The cost for disposal should also be measured. However, it is ignored as the government end-of-life scenarios at the time did not calculate this cost. Any assessment of theirs does not correspond to reality.

Surely the economic evaluation in which the site area is constructed with prefabricated systems commercially present provides a lower result than the real situation.

The materials/components that constituted the safety systems are owned by the municipality. By reusing, the public administration reduces the cost of transport to temporary storage and has the possibility of balancing the cost of the disassembly (against it) with the rent of the site services to the enterprises. The public administration, not having to provide for transportation of site services once they are built, can ensure competitive prices to the companies that purchase the prefabricated systems that must also include transportation in the price. Also, the enterprise has an advantage in the rent of the site services to a profitable price and in the saving of the time otherwise necessary for the organisation of the site (which translates into economic savings).

The construction of the site services with reused materials has a cost 21% lower than the construction of the same structures with prefabricated systems.

Environmental convenience

The assessment of the environmental impact coming from the construction of site services and reusing the materials derived from the selective demolitions in restoration interventions situated in the L'Aquila territory is made with the IPCC 2007, 100 year method. It considers the following phases: production, use and end-life that characterise the life cycle. Only the assessment of the impact of the production phase is believed to be a determinant.

The evaluation is aimed at comparing systems on the market in order to determine the convenience to the construction of site services as previously described. The use phase of the compared situations is similar in how the site services are built with materials resulting from selective demolitions than with new materials on the market. It also assumes that constructive features for both systems are suitable for the use of renewable energy sources through the positioning on the roof of photovoltaic panels. This phase, then, can be neglected.

In both cases for the end-of-life phase, respectable scenarios (reuse, recycling and energy recovery) are considered. They have a lower impact compared to the environmental damage from the production phase. This phase can be approximated to have zero impact.

It follows that the environmental impact assessment is influenced strongly by the phase of production and by the number of years in which this impact is depreciated. Greater is the number of years of use and lower is the environmental impact borne by every year, i.e. the environmental damage is distributed over time.

By taking into consideration the services as previously described, both in terms of size and technology, the assessment of the impact of the production phase is carried out considering a life of temporary structures in the site equal to 15 years.

A life of 21 years is calculated for reused elements (6 years with function of safety systems and 15 years with function of site preparations). For new elements (connectors, insulating and foundations) a life equal to that of 15 years is calculated for the structure.

The environmental impact of the production of materials that constitute the restroom, amounted annually to 0.85 ton CO2-eq. The offices amounted annually to 0.22 ton CO2-eq. The changing room equalled 0.32 tons CO2-eq and the refectory amounted annually to 0.82 ton CO2- eq. The annual environmental impact of the phase of production of materials that constitute the entire site area formed by a common refectory, restroom, three changing rooms and three offices amounts to 3.3 tons CO2-eq. The overall environmental impact is equal to 61 tons of CO2-eq.

For a comparative purpose, the prefabricated modules commonly used in Italy for the services of the site were taken as reference.

The constructive system consists of a bearing structure made with a steel frame and horisontal and vertical closures consisting of sandwich panels that have external coating made with corrugated galvanised steel, mineral wool insulation (100 mm thickness) and interior finishes made with chipboard panels. The modules are lifted off the ground thanks to steel profiles equipped with support bases. An area of 1 sqm consists of 13.5 kg of steel profiles, 22 kg of galvanised steel sheet, 2 kg of mineral wool insulation and 0.1 mc of particleboard.

The closures have a transmittance of 0,40 W/sqmK.

Hypothesising to build the same site area with systems actually commercially present and considering a useful life of the structures equal to 15 years, the annual environmental impact of the production phase of the new materials is equal to 6.5 ton CO2-eq. If to such impact we would also add the environmental impact for the non-use of the available elements derived by the selective demolitions (calculating for them a life cycle of 6 years) and consider the product fractions and quantities equal to those that could be potentially reused for the construction of the same site services, the annual environmental impact will be equal to 15 ton CO2 -eq.

The comparison made presents a better situation than the actual situation. While in cases of reuse of elements

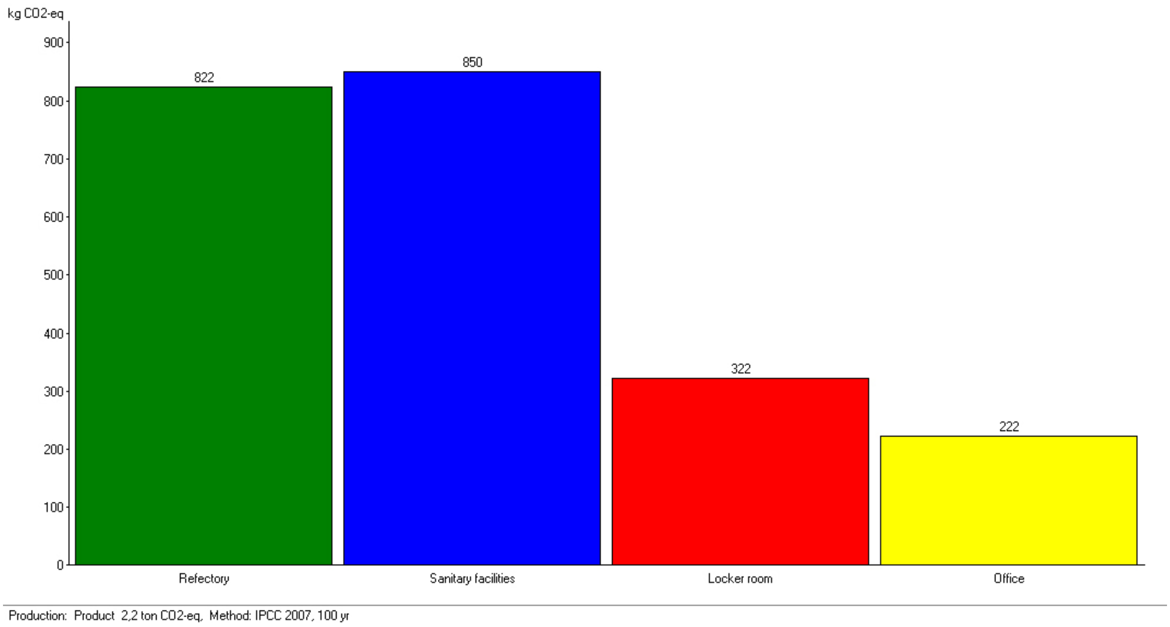


Fig. 23 _ Environmental impact of the production of the designed site services

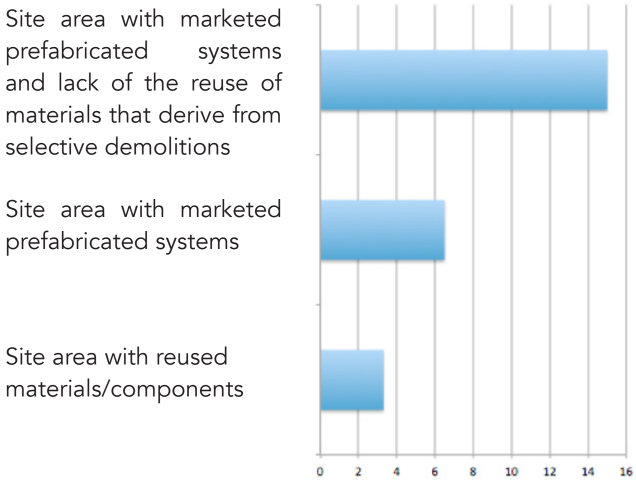


Fig. 24 _Environmental annual impact of production of the common site with designed systems in comparison with the systems on the market

that comes from a site of nearby selective demolitions, the impact of transportation is almost zero, in cases of using prefabricated elements commonly present commercially to the considered impact, it is necessary to also add the impact that derives from transportation, with consequent increases for the reuse convenience.

The predisposition of a common area with a planned use of the enterprises that work in construction sites reduces the environmental impact deriving from the production and the transport. The common projected area can be used by 25 enterprises[39].

In the event that the common area is not prepared, every business has to organise its own construction services. Consequently, 25 restrooms, 25 changing rooms, 2 offices and 25 refectories have to be manufactured and transported. Whereby the common area has been sized for simultaneous use by 3 companies. The environmental impact in the preparation of a common area with programmed use is about 22 times lower compared to the case where each company provides individually for its own site services.

If we consider that the common area is made with reused materials/components derived from selective demolition, the environmental advantage increases. In fact, for the realisation of the common area, the annual environmental impact of production of materials/components resulting from selective demolitions (3.3 tons CO2-eq) is less than 49% of the annual environmental impact would occur if the same area was built with prefabricated systems (6.5 tons CO2-eq).

By taking into account the environmental impact deriving from the non-reuse of materials/components resulting from selective demolition and the construction of site services with prefabricated modules, the environmental damage caused by the annual production (15 ton CO2-eq) is 78% greater than the production impact of the common area made with reused materials (3.3 tons CO2-eq).

Therefore, the convenience of reuse, according to the proposed methodological-operative process, is evident.

The additional ease that comes from the use of material at "zero meter" with an almost zero impact of transport has to also be considered. When prefabricated modules are used, they undergo further transport.

When these systems are bought or rented, the businesses prefer companies in the province of L'Aquila.

When, instead, the prefabricated systems are owned by the same outside companies working on reconstruction, they are transported from the company warehouse (located in other parts of Italy) to the construction site. In both cases the impact of transport negatively affects the environmental assessment.

By comparing the data of the environmental impact to the production of services made with reused materials, it is noted that the changing room and offices, which have less steel and more wood, are minor contributors to environmental damage.

Convenience in reuse is directly proportional to the values of the environmental damage.

The greater the environmental impact of production is, the greater is the convenience of reuse. The life of the element increases the number of years and the cushioning time of the damage. It also decreases the portion of annual impact.

In general, the reuse of the steel is a more sustainable operation than the reuse of wood, due to the greater impact of production given the same amount of material. Safety systems placed in L'Aquila consist mostly of steel components (70%) and to a lesser extent of wood elements (25%). As evidence shows, their reuse is a worthy operation in terms of environmental impact.

Logistic convenience

The preparation of a common site plan and the joint planning of reconstruction limits the problems of interference from the building site and frees traffic.

The reuse of materials resulting from selective demolition allows the government to decrease the burden of transport, storage and disposal of a huge amount of material.

The companies, however, have the advantage of not having to arrange building services (transport and assembly) and can employ their forces only for the reconstruction of buildings.

In addition to responding to the variable needs present on site, the reversibility, adaptability and flexibility of the designed construction systems represent an incentive for future reuse of building structures with other uses beyond the yard. An additional life cycle is assumed.

The logistical burden that results from carrying out the processing operations and dimensional adjustment of the elements is balanced by a significant increase in reusability.

8.5 _The permanent endogenous reuse.

The safety systems must gradually be dismantled with the progress of the recovery of the building to prevent the collapse of the structure and ensure safety conditions for workers. So it is possible an immediate reuse of the dis-

mantled materials/components that can be inserted in the reconstruction project, i.e. the permanent endogenous reuse.
The materials/components must ensure sufficient residual performances in their state at the moment of disassembly or only with the help of reconditioning treatments that can happen on the work site.
In such a way, in addition to the advantages deriving from the reuse of the materials/components from an environmental and economic point of view, logistical advantages are obtained in the sourcing time and in the downsizing of the storage areas (and consequently of the site size). It is reaffirming that in the historic centre of L'Aquila the downsising of the site minimises the problems related to interferences and to difficult manoeuvrability of heavy vehicles. With the aim to obtain these advantages, a time schedule of the works must be set. In this way, it is possible to correlate the disassembly phases of safety systems (that coincide with the sourcing phases of materials) with the relative recovery phases of the building.
The materials /components that present sufficient residual performances can be reused for structural interventions of repair, replacement, strengthening or substitution of the damaged elements, interventions of adaptation or seismic improvement[40].
In addition to the structural type interventions, the materials/ components that constituted the safety systems can also be used for interventions to improve the technological-implant system, such as the creation of air space for the technical implants, the reconstruction of the infills or the bearing part of the floors or for the redistribution of building spatiality through internal partition walls. In any case, it deals with interventions of a permanent nature and that must ensure sufficient performances for a lifetime equal to the nominal life of the building[41].
The type of intervention is strongly conditioned not only by the degradation level of the pre-existence but also by constructive characteristics.
The availability of the materials that constituted the safety systems must, therefore, be compared with the required intervention, with the aim to assess the quality and optimize the type of intervention. Analysing the material, structural and technological compatibility, it is possible to identify the materials preferably usable in function of the pre-existence. First, the material compatibility is analysed, identifying, starting from the features of the material, the risks and the relative safeguards.
For what concerns the wooden elements, it is difficult to suppose the durability because suitable choices of the class of use in function to the wood species, of the possible preserving treatments and the use of constructive modalities preventive to degradation, provide an ideally limited durability to the wooden element. The variability of the boundary conditions is difficult to control in cases of permanent endogenous reuse. Therefore, in such cases it is opportune to oversize the performances of the elements. Consider, for example, the hypothesis for the reuse of wooden beams in the remaking of a roof. When the building is uninhabited, greater humidity will be present; consequently, it will be at greater risk to a biological attack. Therefore, the most durable wood species are more suitable to a permanent use than the less durable species, even when they have characteristics of impregnability such that they can be treated.
The application of a treatment requires, in fact, an economic, logistic and environmental effort that, in cases of reuse, is not very convenient when elements that, for own characteristics, ensure sufficient performances are available.
For what concerns steel elements, a durability of the elements equal to the nominal life of the building (Vn>-50 years) with a class of corrosivity C1 (indoor heated) should be ensured.
With precaution, hypothesising that the building could be unused in a variable period, it can be considered a class of corrosivity C2 (indoor unheated). In addition, the choice of a suitable system for a class of greater corrosivity than the actual increases the durability of the system.
The components with rusting degree Ri 0 and Ri 1 can be reused without suffering treatments. It is necessary to carry out an analysis on the type of used painting to identify the durability, such as the number of years in which the resting degree Ri 3 will be reached. In this way, it will be possible to already programme, in the planning stage, the rate of maintenance interventions.
For the elements with rusting degree Ri 2, it is necessary to assess, in function of the type of painting made, if reusing the elements in its current state of affairs or whether it is necessary to perform reconditioning operations before the installation. Excluding the cases in which a low durability paint was used, if it was used a medium durability paint for the class of corrosivity C3, hypothesising a reuse in a class of corrosivity C2, 12 years are necessary until that the element arrives to a rusting degree Ri 3. Therefore, a clean intervention by sandblasting will be expected with the achievement of the preparation level Sa 21/2 and the next painting to long-term durability (>15 years). In such a way, the required performances by the structure of the building will be met for n. 28 years (12 years + 16 years). It follows that an additional cycle of monitoring and an eventual intervention of reconditioning will have to be provided, according to the some modalities already described, that allows a durability to the elements sufficient until the end of the 44° years of the installation (12 years + 16 years + 16 years).
In function of the real durability of the elements and of the effective nominal life of the building, it will be considered whether it is necessary to make a further reconditioning treatment.
If, instead, it is decided to re-establish the original performing levels before installation, it will be opportune to make a preventive treatment with the achievement of the preparation level St 2 and next preventive treatment by painting.
For the elements with a rusting degree Ri 3 and Ri 4, before reusing it is considered appropriate to make an intervention of secondary or primary preparation (in function of the generalised or localised nature of corrosion) by

sandblasting with compressed air, aimed at achieving the preparation degree Sa 2 1/2 or P Sa 2 1/2 .

After checking the roughness of the surface substrate, a preventive treatment can be applied by painting with durability more than 15 years in function of the corrosivity class C3. Even in this case, like in the previous, it is possible to use a type of painting that has durability higher of 15 years in class C3 and, consequently, equal to 25 years in C2 class.

In such a way, it will be possible to make only one maintenance intervention of the some type at the end of the 25° year, to ensure a durability equal to the nominal life of the building (when Vn= 50 years). Therefore, the number of programmed maintenance interventions is equal to 2.

In cases of reuse without previous treatment on the element, the use of painting with durability equal to 25 years is considered superfluous, considering that such a choice would not be enough to cover the period of expected life for the building.

The analysis of the reuse modalities of elements that are born for the temporariness (as for example, the tube-clamp system or multi-com system) with definitive functions shows the necessity of rigor in the evaluation of durability. While, in fact, the temporary use allows, for its intrinsic characteristics, a frequent monitoring of the elements and, therefore, can rescind from an accurate initial assessment, the definitive use imposes a strict assessment of the residual durability and a careful planning of the maintenance interventions because the inspection of the elements is more difficult and expensive.

A change of destination of use from temporary to permanent and vice versa, requires an evaluation aimed not to underestimate or to overestimate the performance and, in general, it presents results of higher risk than the consistent use with the nature of the element object of analysis.

After having verified that the material compatibility, the structural compatibility and the technology compatibility of the intervention are analysed in a joint way, i.e. in function of the available materials/components and of the performance that must be achieved thanks to the intervention, the variations of resistance, stiffness and ductility of the elements and the variation of the global behaviours of the building are established and they are intersected with the possible technological hypothesis and the relative performance.

If a sufficient compatibility degree is not reached, it will have to resort to using external elements on the construction site, searching them before in the neighbouring reconstruction sites and after in the supply chain.

In function of loads and the type of available elements, the connections must be evaluated, prioritising reversibility, both the junction element (brackets, plates, etc.) and the type of connector (screws, anchor, bolts etc.) must be evaluated.

In cases of a pre-existence in reinforced concrete or masonry and light or medium load, expansion bolts could be used, while in cases of heavy loads, chemical anchors (that have a lower degree of reversibility) and in cases of pre-existence in wood they could be used self-tapping screws.

Operative sheets

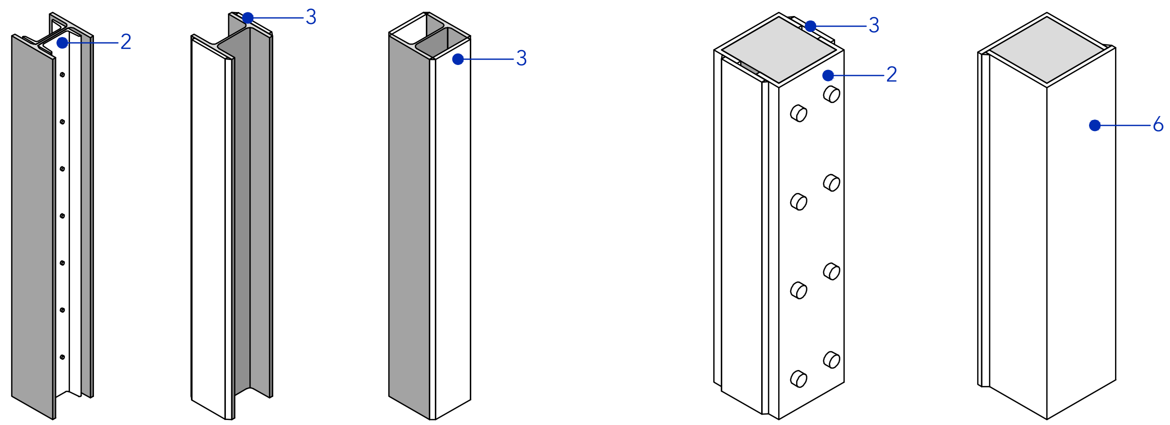
In function of materials/components present in the safety systems, we report the following illustration sheets of permanent reuse aimed at structural, technological or implementation improvement. The variability of the boundary conditions and the multiplicity of found damage prohibits making a comprehensive filing. Therefore, the most common cases are taken into account, by relating the pre-existence (in masonry, wood, reinforced concrete, and more rarely in steel) with the elements available for reuse (profiles UPN, wooden elements, etc.) and neglecting the mode of reinforcement (sprayed concrete, synthetic resins, etc.) or constructive systems (masonry, concrete, etc.) not related to the available resources. The generalisation of the operative phases allows the reproducibility of the intervention also at the presence of boundary-varied conditions, considering the strong correlation with the available materials on the construction site or in the territory.

The sheets offer generic points for reflection about the operative modalities and techniques in the following cases:

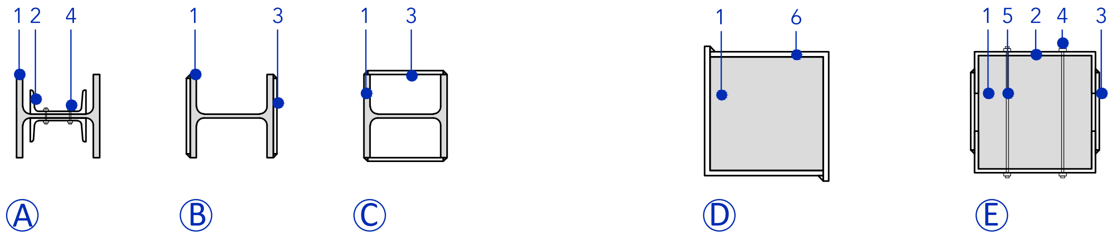
- the consolidation of a pre-existing pillar or steel profiles that affect the geometry and the inertia;
- the consolidation of a pre-existing beam by the addition of metal sheets or profiles, with the function of supporting and/or stiffening;
- the consolidation of a pre-existing floor by the increasing of the inertia of the beams or the main beam;
- the repair of a floor with pre-existence constituted by main beams act to return the bearing capacity to floor, by the reusing of wood or steel beams with the function of secondary beams and by the reusing of corrugated sheets or wooden planks with bearing and load distribution functions;
- the realisation of a new floor on a pre-existence in diaphragms, by the reusing of steel or wood beams and of corrugated sheet or wooden planks with a bearing and load distribution functions;
- the realisation of bracing act to increase the resistance of the structure to horisontal stresses and to redistribute the internal stiffness balancing it compared to the centre of the shear, in order to reduce the torsional vibrations;
- the insertion of tie-rods act to improve the box-behaviour of building, through the connections between the orthogonal walls or between the vertical and horisontal closures, the absorption of thrusts (vaults and arches) or the prevention of collapses out the plane;
- the load redistribution of the structure, caused by the collapse of a pillars line through the insertion of braces and the consolidation of the floors and of the adjacent pillars line or the loads redistribution of the structure through the insertion of a pillars line and the consolidation of floors relating to it;
- the consolidation of an opening through the insertion of the bearing elements of architrave with horizontal and vertical elements for the increasing of the resistance;
- the creation of air space for technical implants in the floor through a floating floor on UPN beams or trusses.

Consolidation of a pre-existing pillar

Steel preesistence | Reinforced concrete preesistence



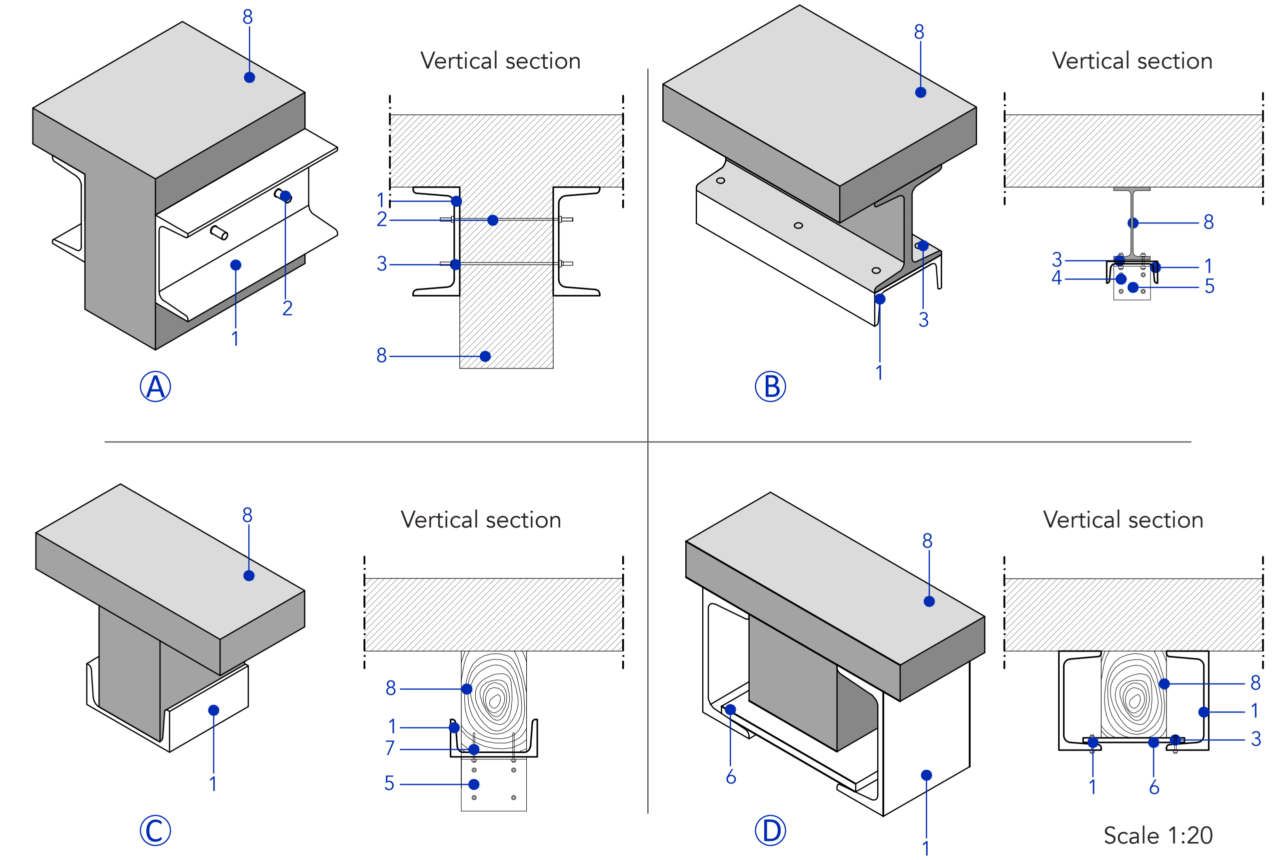
Horizontal section | Horizontal section



Scale 1:20

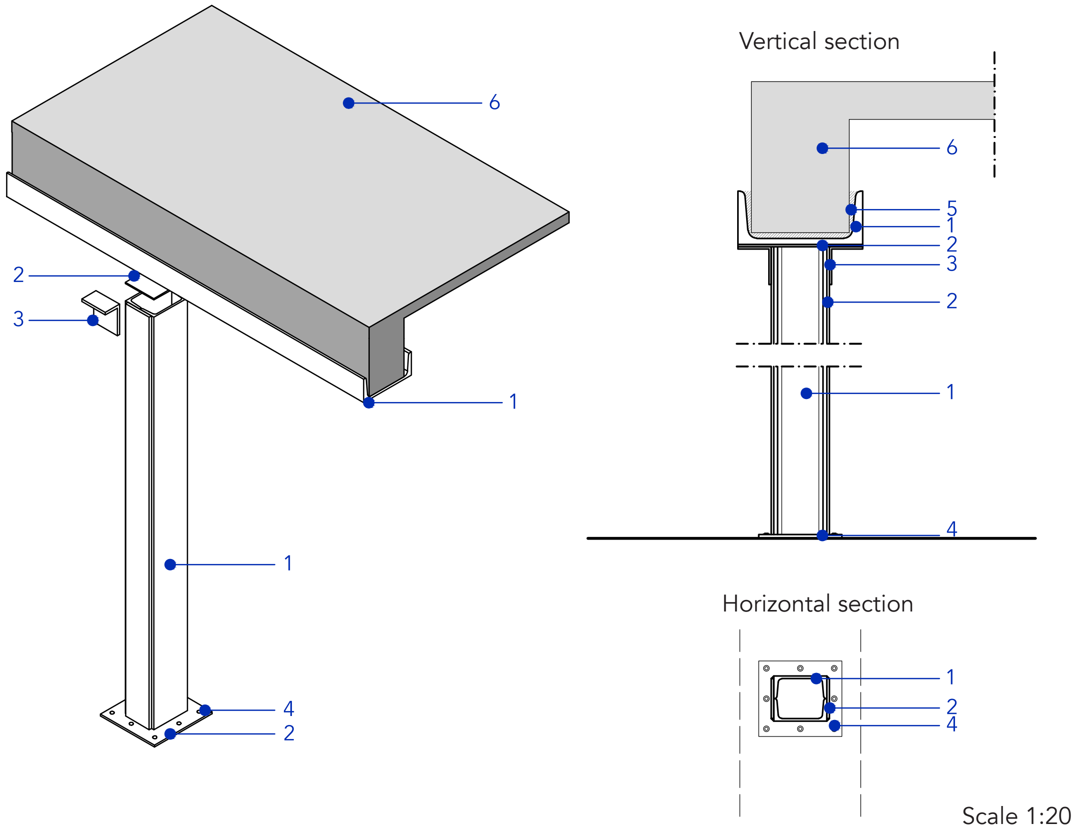
MODE FOR REUSE		
PRE-EXISTENCE - steel pillars - renforced concrete pillars USED ELEMENTS - structural profiles (L, UPN, UPE) - steel plates - bolts for coupling - threaded steel bars REUSED ELEMENTS - structural profiles (L, UPN, UPE) - steel plates - threaded steel bars	WORKING PHASES 0- Cutting of structural profiles, of the plates and of steel threaded rods, when appropriate sizes are not already available. 1- Cleaning of the pre-existing support. STEEL PRE-EXISTENCE_A 2- Drilling of the pre-existing pillar and of the UPN profiles. 3- Positioning of the UPN profiles adjacent to the web plate of the pre- existing pillar. 4- Anchoring by bolting of the UPN profiles to the pre-existing pillar. STEEL PRE-EXISTENCE_ B_C/ REINFORCED CONCRETE PRE-EXISTENCE_ D 2- Positioning of steel plates adjacent to the pre-existing pillar. 3- Welding on edges. REINFORCED CONCRETE PRE-EXISTENCE_E 2- Drilling pre-existing pillar and UPE profiles. 3- Positioning UPE profiles. 4- Positioning steel rods. 5- Locking in adherence by bolting. 7- Welding on edges.	
POSSIBLE VARIATIONS - use of structural profiles with different section (C, T) as a function of the section of the preexisting pillar	LEGEND STEEL PREESISTENCE 1- preexisting pillar 2-structural profile UPN 3- steel sheet 4- bolt (screw- bolt - metal nog)	REINFORCED CONCRETE PREESISTENCE 1- preexisting pillar 2- structural profile UPN 3- steel sheet 4- bolt (bolt - metal nog) 5- steel rod 6- structural profile L

Consolidation of a pre-existing beam



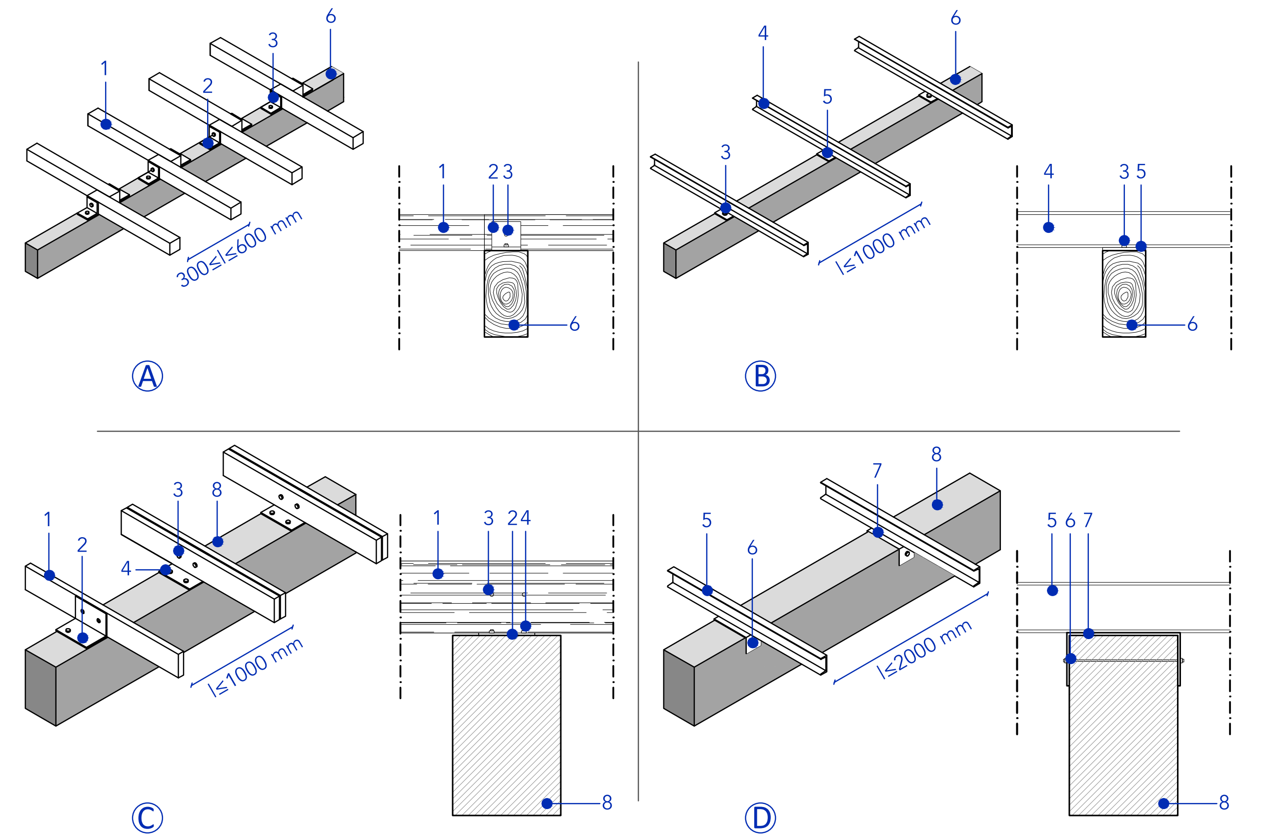
MODE FOR REUSE	
PRE-EXISTENCE -reinforced concrete beams (A) - steel beams (B) - wooden beams (C/D)	WORKING PHASES 0- Cutting of structural profiles, of the plates and of steel threaded rods, when appropriate sizes are not already available. 1- Cleaning of pre-existing support. 2- Drilling of UPN profiles. REINFORCED CONCRETE PRE-EXISTING -A 3- Drilling of pre-existing beam. 4- Positioning of UPN profiles on beams. 5- Insertion of threaded rods. 6- Locking by bolting of the UPN beams to the reinforced concrete beams. STEEL PRE-EXISTENCE_B / WOODEN PRE-EXISTENCE _C 3- Assembly by bolting of L brackets. 4- Positioning of UPN profiles. 5- Anchoring of UPN profiles to brackets and to pre-existing beams. WOODEN PRE-EXISTENCE _D 3- Positioning of the steel plate on UPN profiles. 4- Bolting of the plate to UPN profiles. 5- Positioning and anchoring of the UPN profiles (joined with the backing plate) to supporting the pre-existing beam.
USED ELEMENTS - structural profiles UPN - steel brackets L - steel plates - bolts for coupling - threaded steel bars - screws for wood	
REUSED ELEMENTS - structural profiles UPN - steel brackets L - steel plates - threaded steel bars	
POSSIBLE VARIATIONS - use of structural profiles with different section (ipe, hea, heb) in the cases B, C and D - welding of the profiles in the cases B and D	LEGEND 1- structural profile UPN 2- threaded rod 3- bolt (screw-bolt- metal nog) 4- expansion bolt (bolt with cone plug fitted with ring) 5- bracket steel L 6- steel plate 7- screw for wood 8- preexistence

Reinforcement of a beam by the insertion of a new pillar



MODE FOR REUSE	
PRE-EXISTENCE - wooden beams -reinforced concrete beams - steel beams	WORKING PHASES 0- Cutting of structural profiles, when appropriate sizes are not already available. 1- Vertically welding of steel plates on coupled UPN profiles. 2- Positioning and welding of L profiles on pillar. 3- Positioning and welding of a steel plate on the summit of the pillar and on the horisontal part of the L bracket. 4- Positioning of the anchoring plate. 5- Bolting of the anchoring plate to the ground. 6- Installation of mortar/ glue on UPN profile with greater size. 7- Positioning of UPN profile recessed below the pre-existing beam with the support of props. 8- Positioning and welding of the pillar (UPN beams coupled through steel plates, L brackets, horisontal steel sheet) on the anchoring steel plate stuck into the ground and on the web plate of the UPN profile recessed in the pre-existing beam. 9- Disassembly of supporting props.
USED ELEMENTS - structural profiles UPN - steel brackets L - steel plates - expansion bolts	
REUSED ELEMENTS - structural profiles UPN - steel brackets L - steel plates	
POSSIBLE VARIATIONS - use of structural profiles UPE for support the beam - use of a pillar formed by a single structural profile(ipe, he, scatolare, etc.) - Bolting the support for the beam to the L brackets - support existing beam in punctual way	LEGEND 1- profile UPN 2- steel plate 3- ssteel brackets L 4-expansion bolt (bolt with cone plug fitted with ring) 5- adhesive / mortar 6- preexisting beam

Installation of secondary beams on pre-existing primary beams

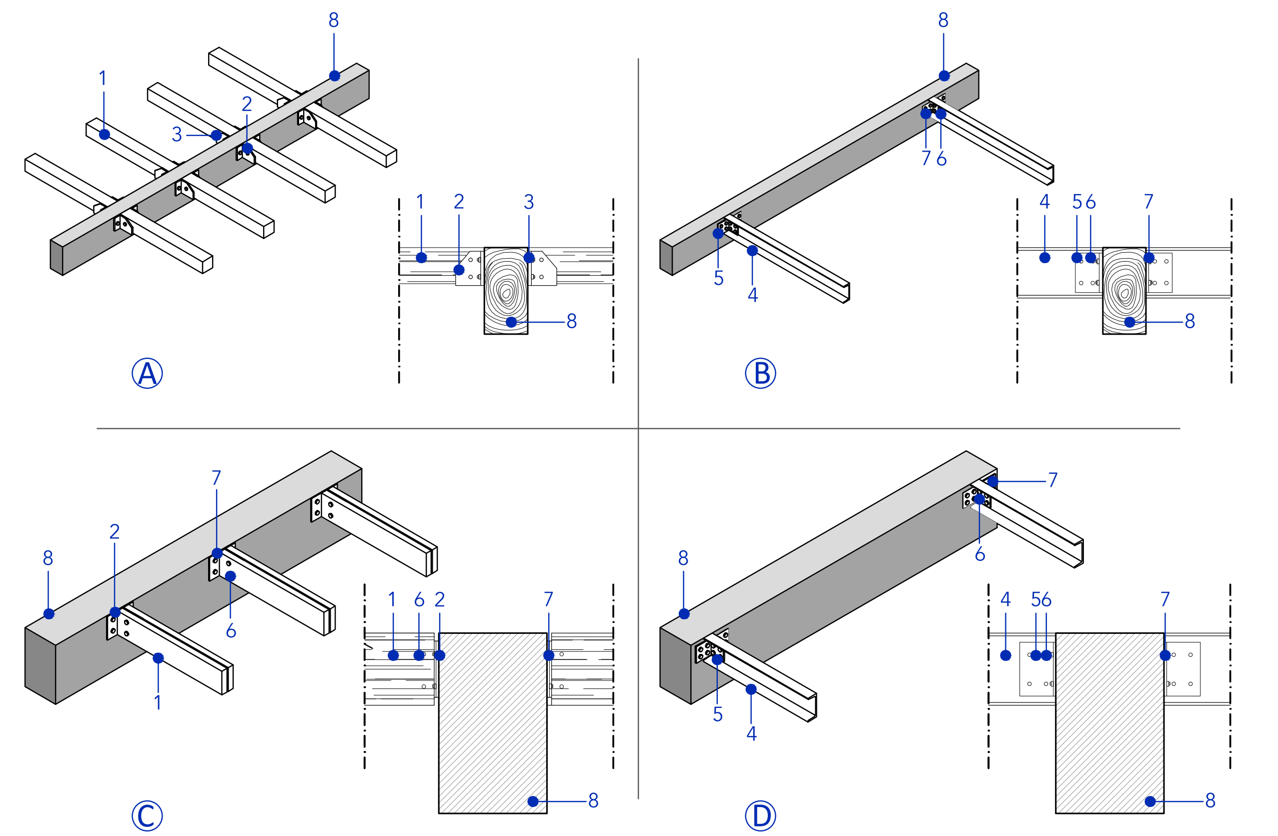


Scale 1:20

MODE FOR REUSE	
PRE-EXISTENCE - wooden primary beam (A/B) - reinforced concrete primary beam (C/D)	WORKING PHASES 0- Cutting of wooden beams (A/B) / of the steel profiles (C/D) , when appropriate sizes are not already available 1- Cleaning of the pre-existing support.
USED ELEMENTS - wooden beams (A/C) - structural profiles UPN (B/D) - steel brackets - steel plates - threaded steel rods - expansion bolts - bolts for coupling - screws for wood	WOODEN PRE-EXISTENCE A / REINFORCED CONCRETE PRE-EXISTENCE_C 2- Positioning of the L brackets /anchoring brackets on the pre-existing beam. 3- Anchoring of the L brackets / anchoring brackets on the pre-existing beam. 4- Positioning of the secondary wooden beams on the pre-existing beam. 5- Screwing of the wooden beams to L brackets/ anchoring brackets. WOODEN PRE-EXISTENCE _B 2- Welding of the UPN profiles on steel plates. 3- Positioning of UPN profiles (joined with plates) on the primary beam. 4- Screwing of the UPN profiles (joined with plates) on the primary beam.
REUSED ELEMENTS - wooden beams (A/C) - structural profiles UPN (B/D) - steel brackets L - steel plates - threaded steel rods	CONCRETE PRE-EXISTENCE_D 2- Drilling of the pre-existing beam. 3- Welding of the UPN profiles to the anchoring brackets. 4- Positioning of UPN profiles (joined with brackets) on the primary beam. 5- Insertion of the threaded rods and locking.

POSSIBLE VARIATIONS	LEGEND		
- use of structural steel profiles of different section - bolting profiles UPN to the anchor brackets in cases B and D - change the type of the bracket according to the load	WOOD PREESISTENCE 1- wooden beam 2- steel bracket L 3- screw for wood 4- profile UPN 5- steel plate 6- preesistence	REIFORCED CONCRETE 1- wooden beam 2- steel bracket 3- bolt for coupling 4- expansion bolt (bolt with cone plug fitted with ring)	PREESISTENCE 5- profile UPN 6- threaded steel rods with bolt 7- anchor bracket 8- preesistence

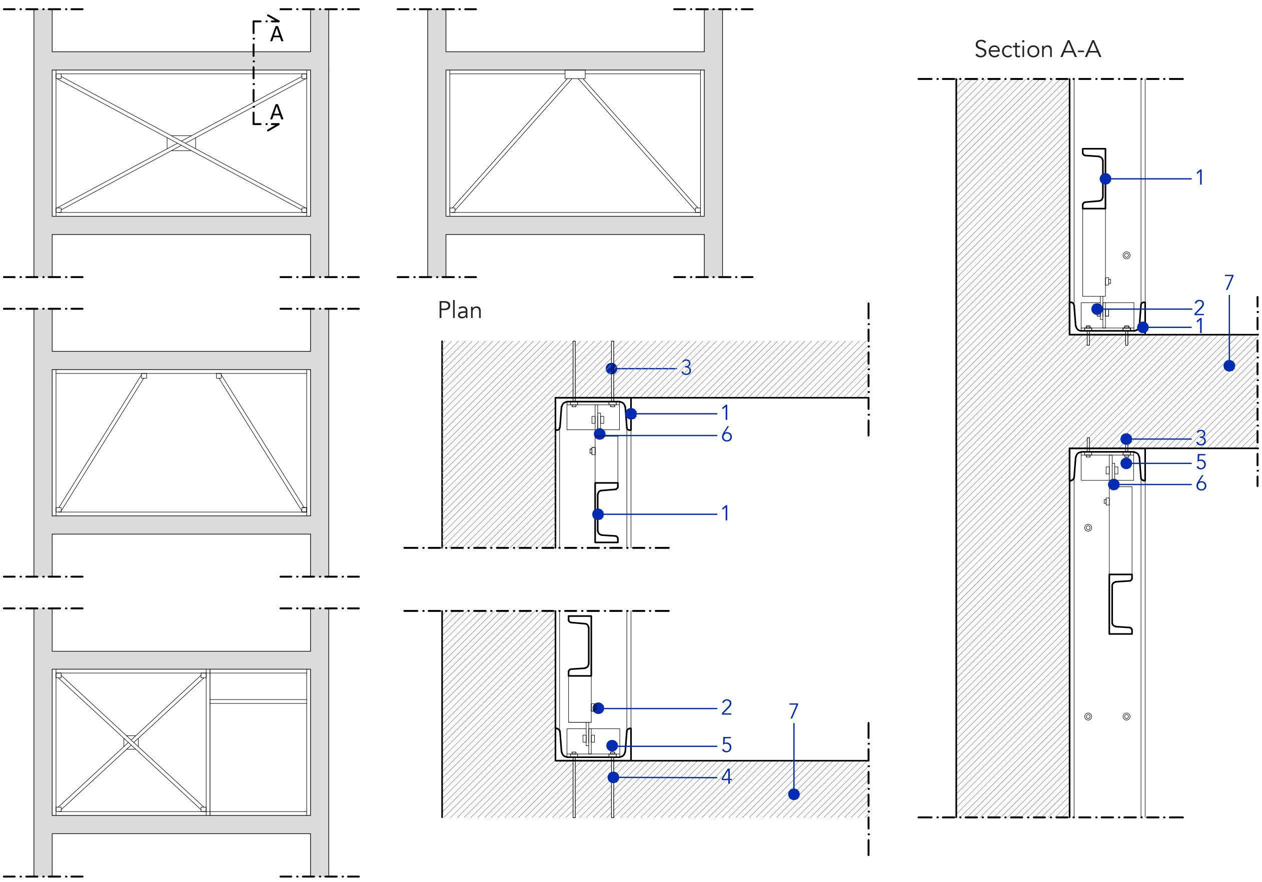
Installation of secondary beams on primary pre-existing beams



Scale 1:20

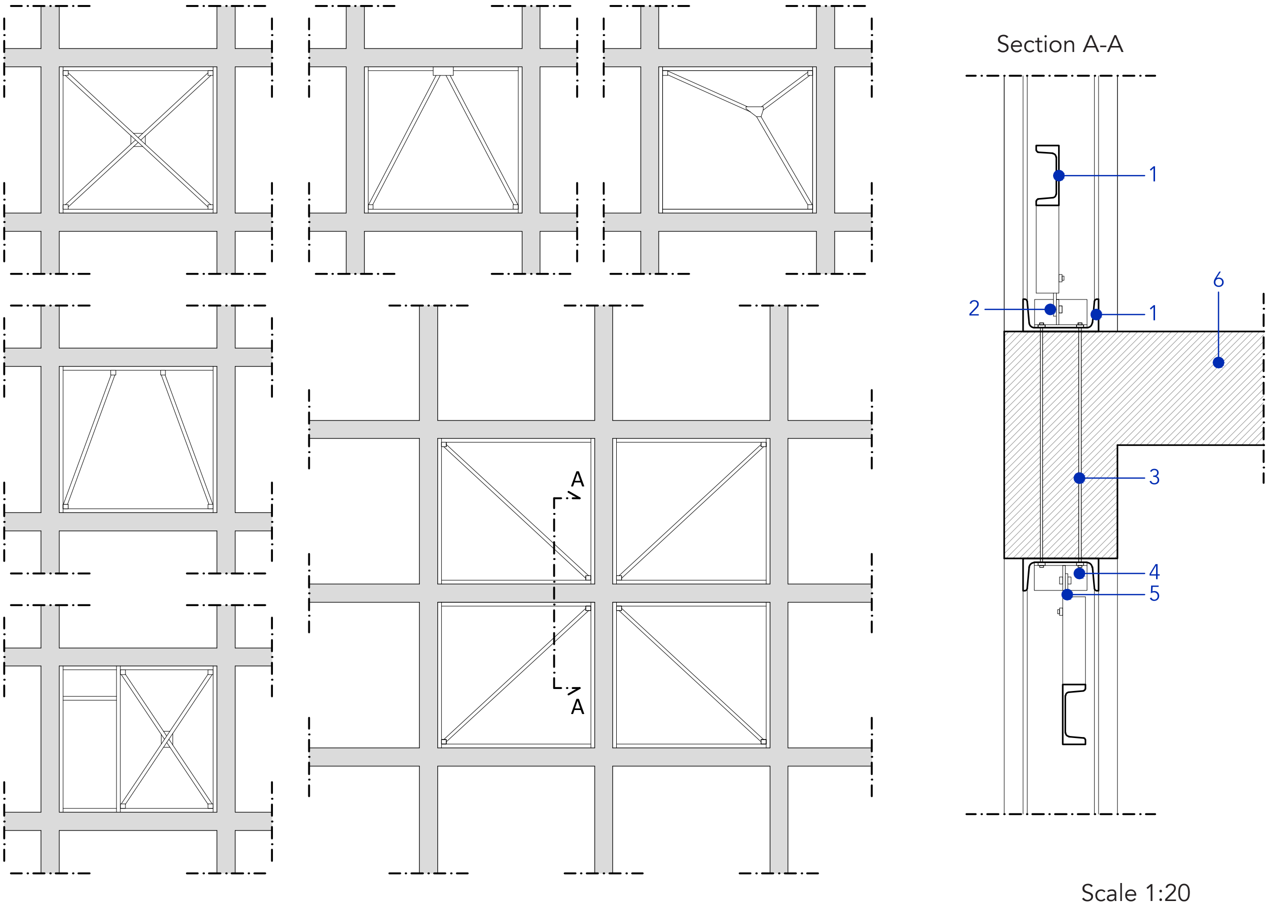
MODE FOR REUSE	
PRE-EXISTENCE - wooden primary beam (A/B) - reinforced concrete primary beam (C/D)	WORKING PHASES 0- Cutting of wooden beams (A/C) / of steel profiles (B/D) , when appropriate sizes are not already available 1- Cleaning of the pre-existing support. 2- Positioning of the L brackets/anchoring brackets on the pre-existing beam. 3- Positioning of the L bracket/ anchoring brackets on the pre-existing beam, by screws (A/B)/ by expansion bolts (C/D). 4- Positioning of the secondary wooden beams (A/B)/ of steel profiles (C/D). 5- Screwing of the wooden transoms to the anchoring brackets (A/C)/ bolting of the UPN profiles to L brackets (B/D).
USED ELEMENTS - wooden beams (A/C) - structiral profiles UPN (B/D) - steel brackets - expansion bolts - bolts for coupling - screws for wood	
REUSED ELEMENTS - wooden beams (A/C) - structiral profiles UPN (B/D) - steel brackets	
POSSIBLE VARIATIONS - use of structural steel profiles of different section (heb, ipe, etc.) - change the type of bracket or connection in function of load	LEGEND 1- wooden beam 2- steel bracket 3- screw for wood 4- profile UPN 5- steel bracket L 6- bolt for coupling 7- expansion bolt (bolt with cone plug itted with ring) 8- preesistence

Realization of bracing on pre-existing masonry



MODE FOR REUSE	
PRE-EXISTENCE - masonry structure USED ELEMENTS - structural profiles UPN - steel plates - anchor brackets - bolts for coupling - expansion bolts - steel bars REUSED ELEMENTS - structural profiles UPN - steel plates - anchor brackets - steel bars	WORKING PHASES 0- Cutting of structural profiles, of the plates and of steel threaded rods, when appropriate sizes are not already available 1- Cleaning of the pre-existing support. 2- Drilling of masonry diaphragms and of UPN profiles. 3- Vertical positioning of UPN profiles adjacent to pre-existing diaphragms. 4- Insertion of the steel bars and bolting of the UPN profiles to diaphragms. 5- Horisontal positioning of the UPN profiles adjacent to pre-existing floors. 6- Bolting of the UPN profiles to pre-existing floors. 7- Bolting of the anchoring brackets to UPN profiles. 8- Bolting of the anchoring plates to UPN profiles that have the function of bracing. 9- Bolting of UPN profiles to anchoring brackets by steel plates joined to them.
POSSIBLE VARIATIONS - use of structural steel profiles of different section (heb, ipe, etc.) according to the preesistence - se of anchorage method different depending on the preesistence (type of masonry, type of floor etc.)	LEGEND 1- structural profile UPN 2- bolt for coupling (screw-bolt- metal nog) 3- expansion bolt (bolt with cone plug itted with ring) 4- barra in acciaio 5- anchor bracket 6- steel plate 7- preesistence

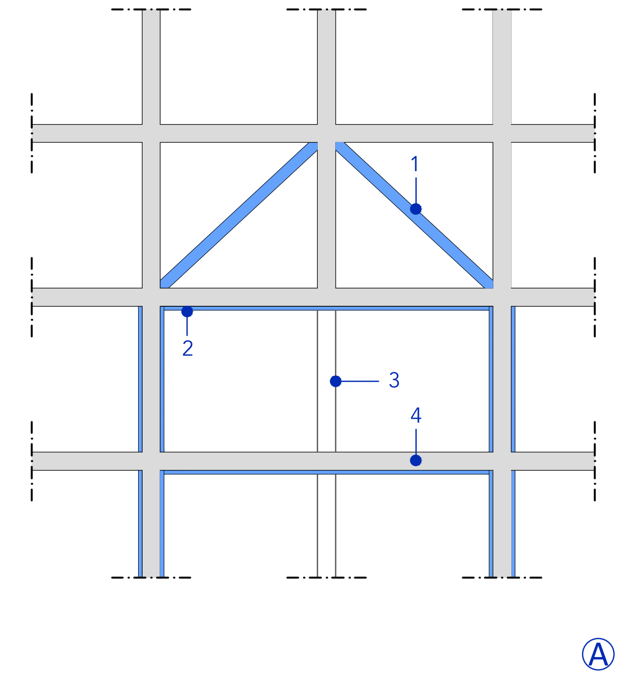
Realization of bracing on pre-existence in reinforced concrete



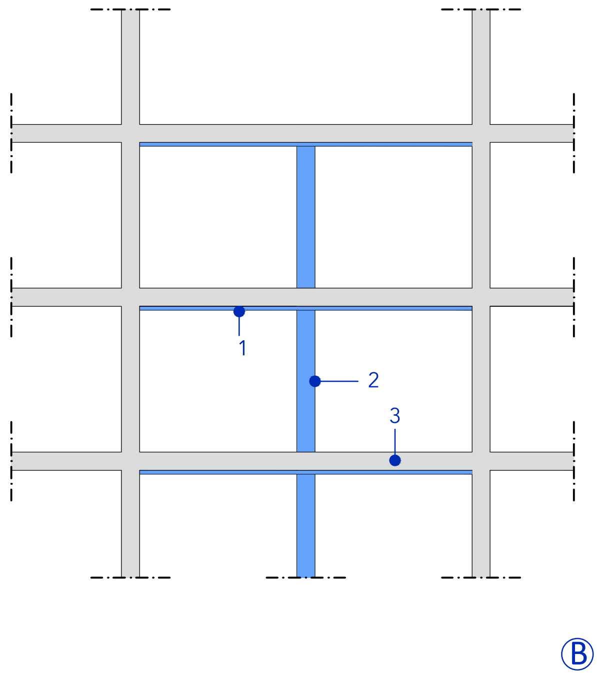
MODE FOR REUSE	
PRE-EXISTENCE - reinforced concrete structure	WORKING PHASES 0- Cutting of structural profiles, of the plates and of steel threaded rods, when appropriate sizes are not already available 1- Cleaning of the pre-existing support. 2- Drilling of the pillars and of the pre-existing beams and of the UPN profiles. 3- Vertical positioning of UPN profiles adjacent to pre-existing pillars. 4- Insertion of the steel bars and bolting of the UPN profiles to pillars. 5- Horizontal positioning of the UPN profiles adjacent to pre-existing beams. 6- Insertion of the steel bars and bolting of the UPN profiles to beams. 7- Bolting of the anchoring brackets to UPN profiles. 8- Bolting of the anchoring plates to UPN profiles that have the function of bracing. 9- Bolting of UPN profiles to anchoring brackets by steel plates joined to them.
USED ELEMENTS - structural profiles UPN - steel plates - anchor brackets - bolts for coupling - steel bars	
REUSED ELEMENTS - structural profiles UPN - steel plates - anchor brackets - steel bars	
POSSIBLE VARIATIONS - use of structural steel profiles of different section (heb, ipe, etc.) according to the preexistence	LEGEND 1- structural profile UPN 2- bolt for coupling (screw-bolt- metal nog) 3- steel bar 4- anchor bracket 5- steel plate 6-preesistence

Redistribution of the loads of the structure

Redistribution of loads
following the removal of a line of pillars



Redistribution of loads
with the addition of a line of pillars



Scale 1:20

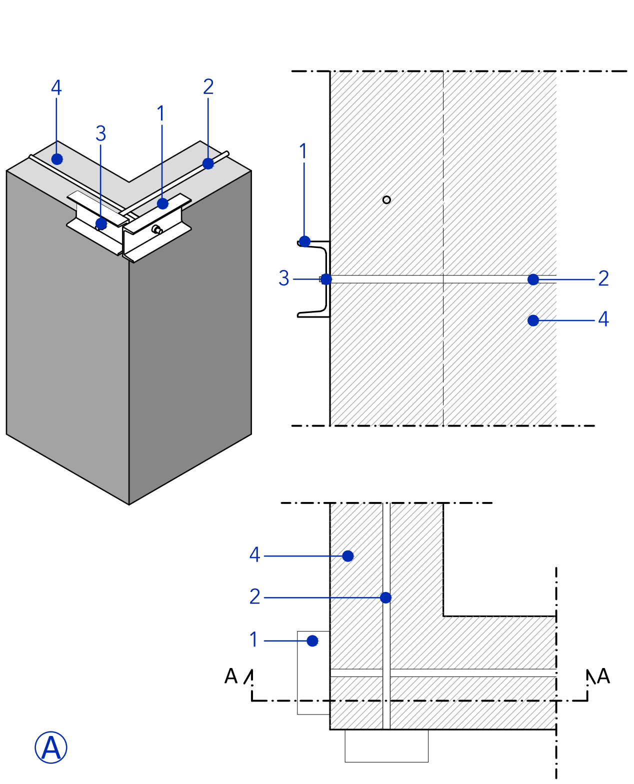
<table>
<tr><th colspan="3">MODE FOR REUSE</th></tr>
<tr><td>PRE-EXISTENCE
- reinforced concrete structure</td><td colspan="2" rowspan="3">WORKING PHASES
0- Cutting of structural profiles, when appropriate sizes are not already available.
1- Cleaning of the pre-existing support.

DELETING A LINE OF PILARS_A
2- Reinforcement of the pillars line adjacent to the pillars line to delete (please see specific sheet).
3- Coupling by bolting of the UPN profiles along the web plate.
4- Bolting of anchoring brackets to the pre-existence structure in the corner points of the upper floor to the floors where is deleted the pillar line.
5- Boiling of the UPN coupled beams to the anchoring brackets in a horisontal position.
6- Shoring of the floors.
7- Elimination of the pillars line from top to bottom.
8- Reinforcement of the floors referred to the eliminated pillars line and progressive disassembly of the shoring (please see specific sheet).

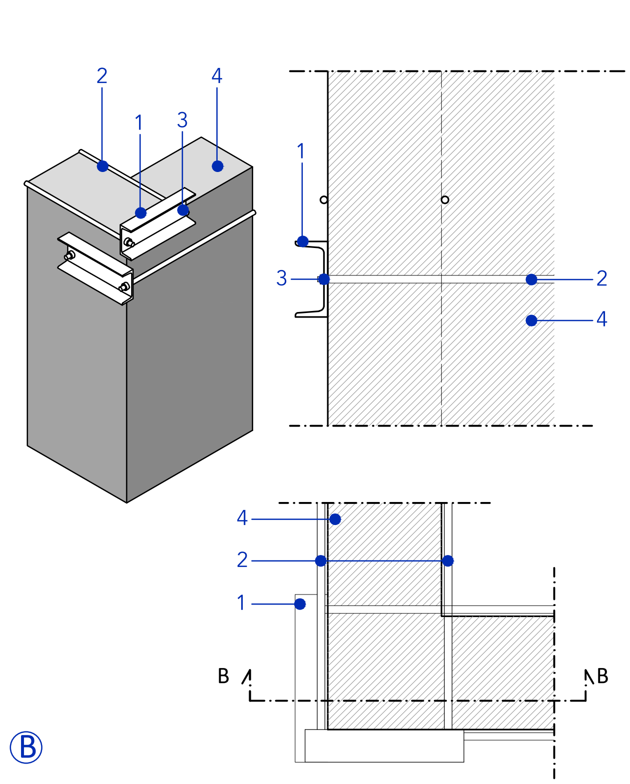
ADDITION OF A LINE OF PILLARS _B
3- Reinforcement of the beams by the insertion of a new line of pillars (please see specific sheet).</td></tr>
<tr><td>USED ELEMENTS
- structural profiles UPN
- steel bracket L
- steel plates
- bolts for coupling
- expansion bolts
- threaded steel bar</td></tr>
<tr><td>REUSED ELEMENTS
- structural profiles UPN
- steel bracket L
- steel plates
- threaded steel bar</td></tr>
<tr><td>POSSIBLE VARIATIONS
- use of structural steel profiles of different section (C, T) according to the preesistencea</td><td>LEGEND
REMOVAL AF A LINE OF PILLARS_A
1-bolted beams UPN
2-consolidation beam UPN
3- eliminated pillar
4- preesistence</td><td>
ADDITION OF A LINE OF PILLARS _B
1-c onsolidation beam UPN
2- profiles UPN coupled by bolting
3- preesistence</td></tr>
</table>

Restoration of the box- behaviour by tie-rods

Tie rod drilling of the wall



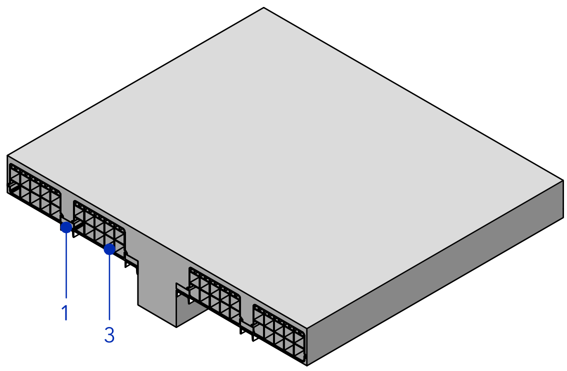
Double tie rods at the sides of the wall

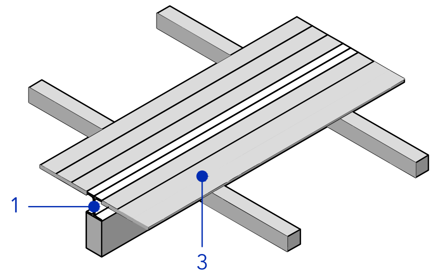


Scale 1:20

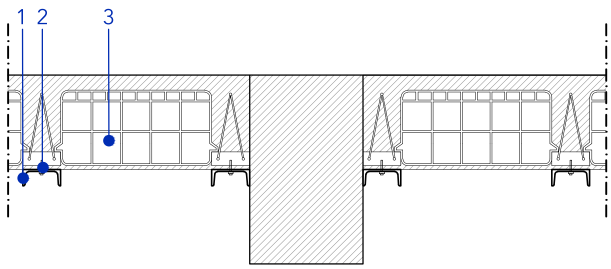
MODE FOR REUSE	
PRE-EXISTENCE - bearing structures with diaphragms	WORKING PHASES 0- Cutting of structural profiles and of steel threaded rods, when appropriate sizes are not already available 1- Cleaning of the pre-existing support. 2- Marking of the levels and axes of the rods. 3- Drilling of the UPN profiles and of masonry. 4- Eventual consolidation of masonry in the anchoring point. 5- Insertion of the rods with eventual presence of sheath. 6- Positioning of the UPN profiles of contrast. 7- Tensioning of the tie rods. 8- Sealing of the holes and grooves.
USED ELEMENTS - structural profiles UPN - bolts for coupling - steel bars	
REUSED ELEMENTS - structural profiles UPN - bolts for coupling - steel bars	
POSSIBLE VARIATIONS - Use of structural profiles with different section or plates of contrast as a function of preesistence	LEGEND 1- structural profile UPN 2- steel tie rod 3- anchor bolt 4- preesistence

Consolidation of a floor

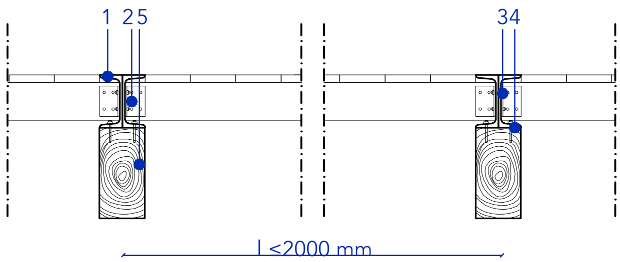




Longitudinal section



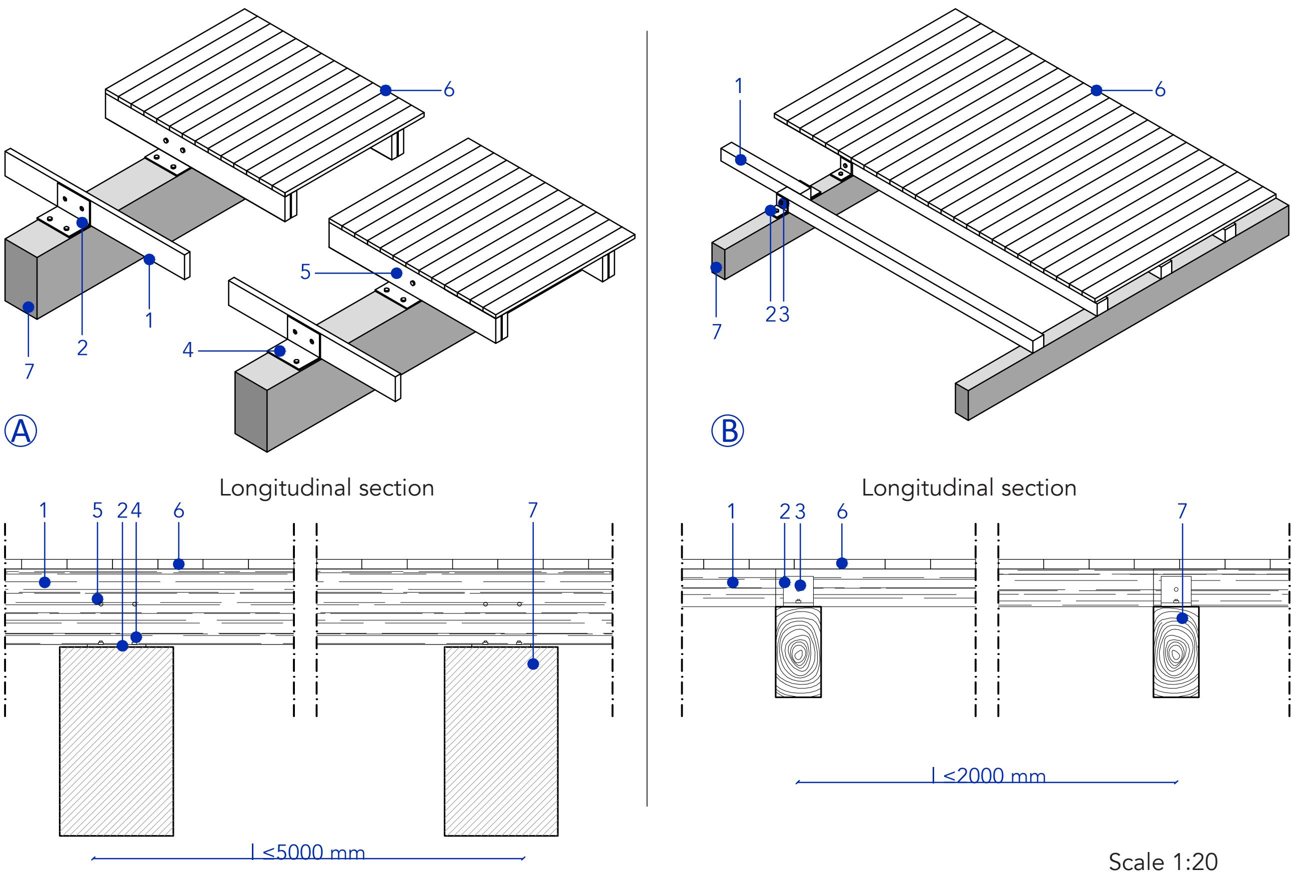
Longitudinal section



Scale 1:20

MODE FOR REUSE		
PRE-EXISTENCE - hollow block floor - wood floor	WORKING PHASES 0- Cutting of structural profiles, when appropriate sizes are not already available. 1- Cleaning of the pre-existing support. HOLLOW BLOCK PRE-EXISTENCE- A 2- Drilling of the pre-existing floor and of the UPN profiles. 3- Positioning of the UPN profiles with the web plate adjacent to the floor. 4- Anchoring of the UPN profiles to the pre-existing floor by expansion bolting. WOODEN PRE-EXISTENCE _B 2- Drilling of the UPN profiles. 3- Coupling by bolting of the UPN profiles. 4- Bolting of steel L brackets to the UPN profiles. 5- Positioning and screwing of the UPN profiles to the wooden beam. 6- Positioning and screwing of wooden joists to the UPN profiles by steel L brackets. 7- Screwing of wooden boards to wooden joists.	
USED ELEMENTS - structural profiles UPN - bolts for coupling - expansion bolts - screws for wood - steel bracket L		
REUSED ELEMENTS - structural profiles UPN - steel bracket L		
POSSIBLE VARIATIONS - use of structural steel profiles of different section (C, IPE, etc.) according to preesistence - variation of the type of connections depending on the loads	LEGEND HOLLOW BLOCK FLOOR_A 1- structural profile UPN 2- expansion bolt (bolt with cone plug itted with ring) 3- preesistence	WOOD FLOOR 1- coupled structural profiles UPN 2- steel bracket L 3- bolt for coupling (screw-bolt- metal nog) 4- screw for wood 5- preesistence

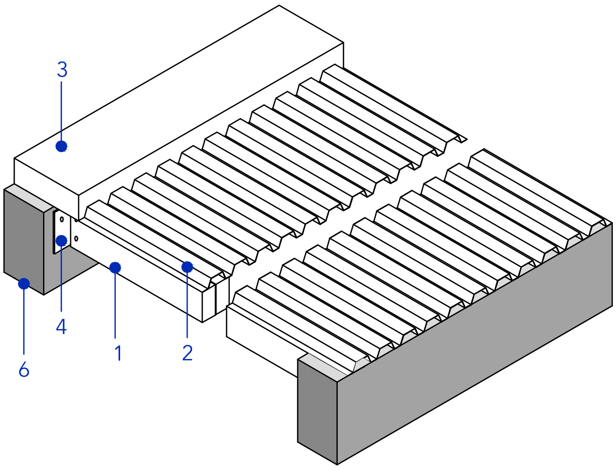
Installation of floor on pre-existing primary beams

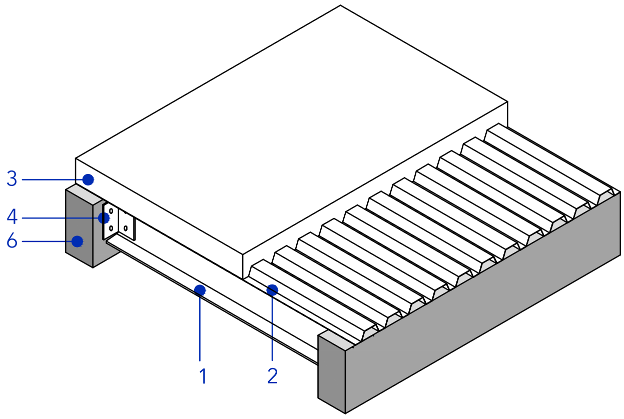


Scale 1:20

MODE FOR REUSE	
PRE-EXISTENCE - wooden primary beam - reinforced concrete primary beam	WORKING PHASES 0- Cutting of wooden beams and of wooden planks, when appropriate sizes are not already available 1- Cleaning of the pre-existing support. 2- Positioning and anchoring of L squared, by expansion bolts (A) or screws for wood (B) on primary beams. 3- Drilling of secondary wooden beams (A) and positioning of secondary beams (A/B) 4- Locking of the secondary beams to the primary beams by bolting (A)/screwing (B). 5- Eventual installation of bracing. 6- Positioning of the wooden planks. 7- Screwing of wooden planks to the secondary beams.
USED ELEMENTS - wooden beams - steel brackets - bolts for coupling - expansion bolts - screws for wood - wooden boards	
REUSED ELEMENTS - wooden beams - steel brackets - wooden boards	
POSSIBLE VARIATIONS - change the type of connection between the primary and secondary beams as a function of load - use of structural elements of load distribution different from wooden boards	LEGEND 1-secondary beam: wooden beams coupled (A) / joists (B) 2- steel brackets L 3- screw for wood 4- expansion bolt (bolt with cone plug itted with ring) 5- bolt for coupling (screw-bolt- metal nog) 6- wooden boards 7- preexisting primary beam

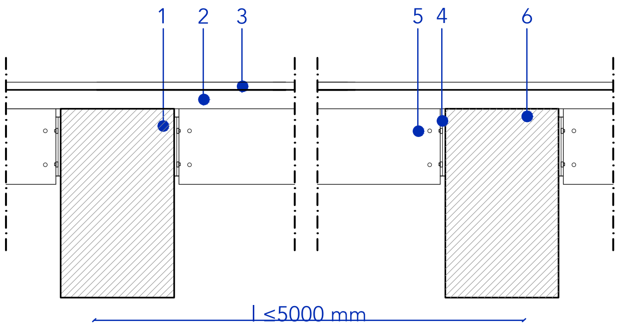
Installation of floor on primary pre-existing beams





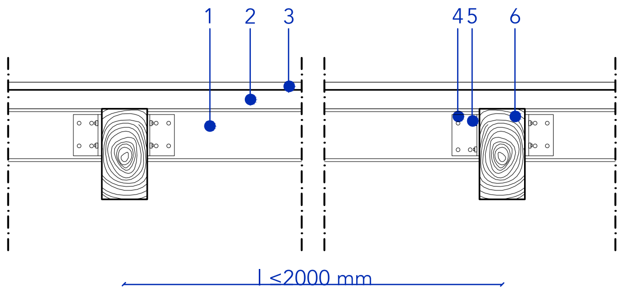
Ⓐ

Longitudinal section



Ⓑ

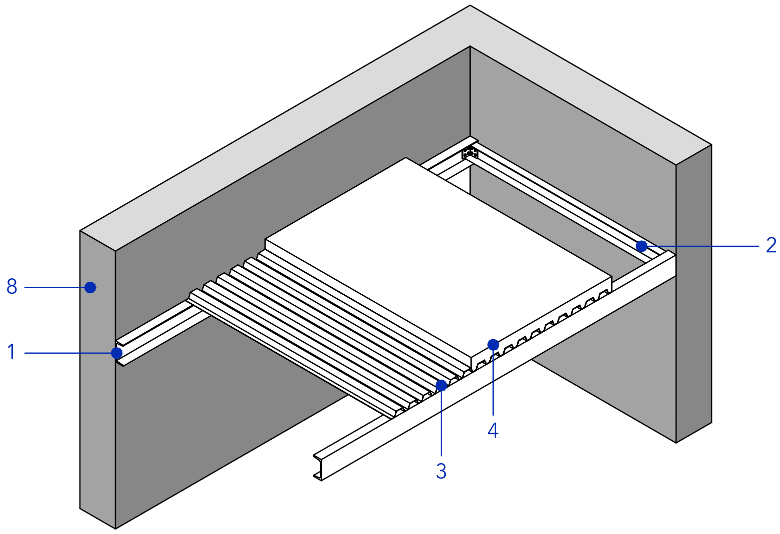
Longitudinal section



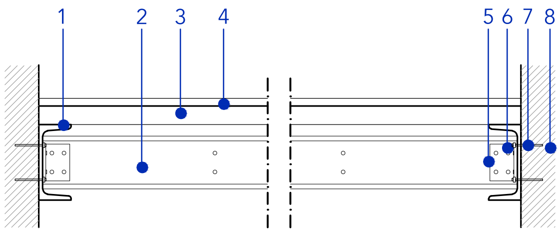
Scale 1:20

MODE FOR REUSE	
PRE-EXISTENCE - wooden primary beam - reinforced concrete primary beam USED ELEMENTS - wooden beams (A)/ structural profiles UPN (B) - corrugated sheet - steel bracket L - bolts REUSED ELEMENTS - wooden beams (A)/ structural profiles UPN (B) - corrugated sheet - steel bracket L	WORKING PHASES 0- Cutting of wooden beams (A) of steel profiles (B) and of the corrugated sheet, when appropriate sizes are not already available 1- Drilling of secondary beams (UPN or wooden beams). 2- Positioning and anchoring of L brackets, by bolting (the type of bolts depends on the pre-existence). 3- Positioning secondary beams. 4- Locking by bolting of the secondary beams to primary beams. 5- Eventual installation of bracing. 6- Positioning of the corrugate sheet. 7- Assembly of formworks for containing the casting of concrete. 8- Positioning of the electro-welded mesh. 9- Casting of concrete.
POSSIBLE VARIATIONS - use of structural steel profiles of different section (heb, ipe, etc.) - use of structural elements of load distribution different from the corrugated sheet	LEGEND 1- secondary beam: wooden beams coupled (A) / profile UPN (B) 2- corrugated sheet 3- reinforced slab with welded 4- steel bracket L 5-bolt (the type of bolt changes depending on the pre-existence) 6- preexisting primary beam

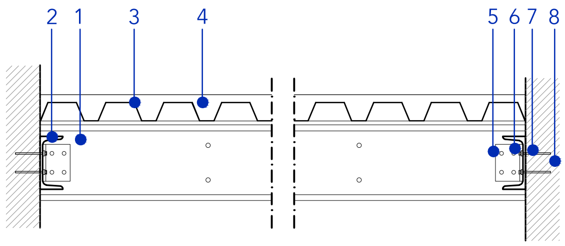
Installation of new floor



Longitudinal section



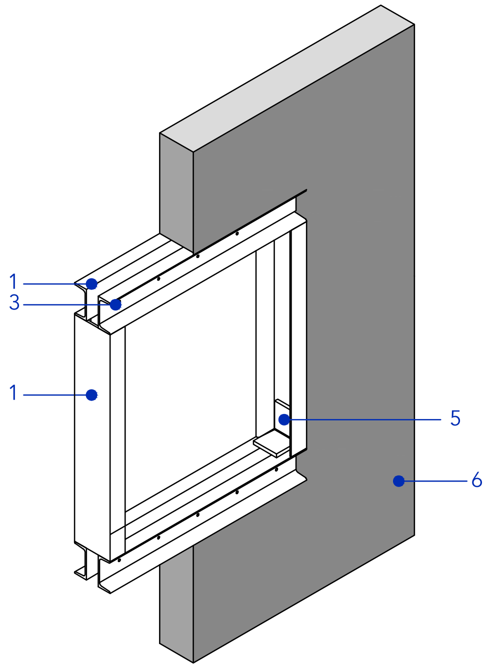
Cross section



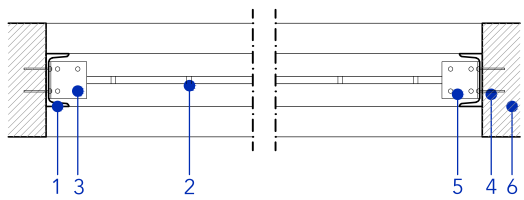
Scale 1:20

<table>
<tr><th colspan="3">MODE FOR REUSE</th></tr>
<tr><td>PRE-EXISTENCE
- bearing structures with diaphragms</td><td colspan="2" rowspan="3">WORKING PHASES
0- Cutting of profiles and corrugated sheet, when appropriate sizes are not already available
1- Drilling of beams and diaphragms.
2- Positioning and screwing of primary beams to the diaphragms.
3- Positioning and screwing of secondary beams to the diaphragms.
4- Screwing of the secondary beams to primary beams by L brackets.
5- Eventual installation of bracing.
6- Positioning of corrugated sheet.
7- Casting of concrete and positioning of the electro-welded mesh.</td></tr>
<tr><td>USED ELEMENTS
- structural profiles UPN
- corrugated sheet
- steel bracket L
- bolts for coupling
- expansion bolts</td></tr>
<tr><td>REUSED ELEMENTS
- structural profiles UPN
- corrugated sheet
- steel bracket L</td></tr>
<tr><td>POSSIBLE VARIATIONS
- use of structural elements of load distribution different from the corrugated sheet (wood panels, prefabricated reinforced concrete panels, etc.)
- installation of braces
- use of secondary wooden beams</td><td>LEGEND
1. primary beam -profile UPN
2. secondary beam - profile UPN
3- corrugated sheet
4- reinforced slab with welded</td><td>5- steel bracket L
6- bolt for coupling (screw-bolt- metal nog)
7- expansion bolt (bolt with cone plug itted with ring)
8- preesistence</td></tr>
</table>

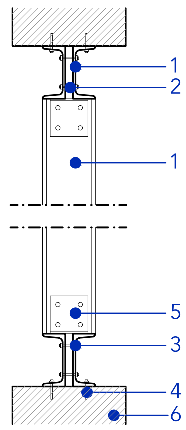
Consolidation of an opening



Horizontal section



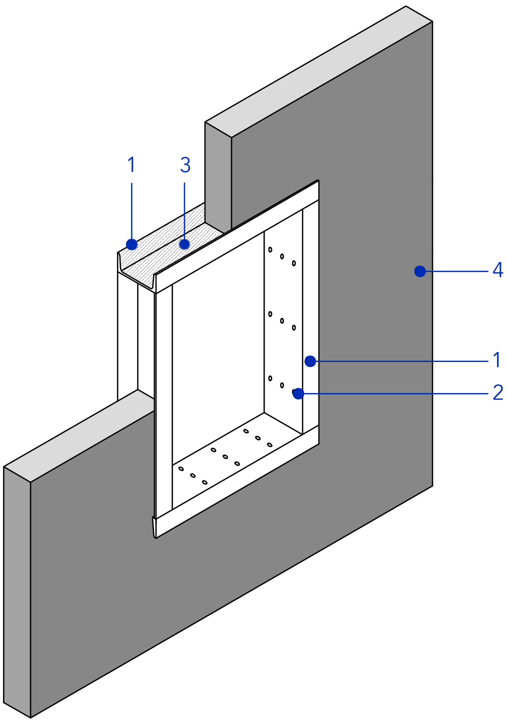
Vertical section



Scale 1:20

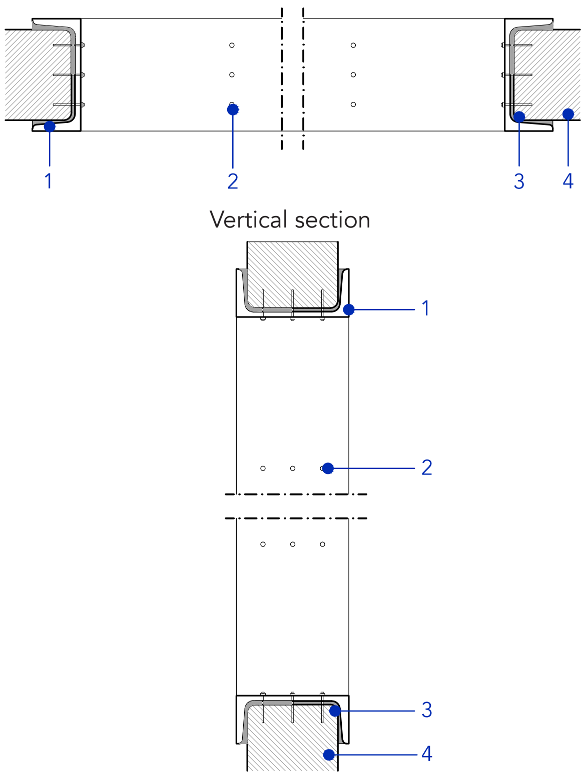
MODE FOR REUSE	
PRE-EXISTENCE - masonry diaphrams - reinforced concrete dia-phragms	WORKING PHASES 0- Cutting of structural profiles, when appropriate sizes are not already available. 1- Cleaning of the support and levelling when it is not in flat. 2- Drilling of 4 beams in correspondence of the coupling points. 3- Coupling of lower beams by screwing and coupling. 4- Positioning of lower beams. 5- Anchoring of lower beams to the bearing structure by expansion bolts. 6- Drilling of the uprights in correspondence of the anchoring points. 7- Positioning of the uprights. 8- Anchoring of the uprights by expansion bolts on the vertical wall. 9- Coupling of upper beams by bolting. 10- Positioning of upper beams. 11- Anchoring of upper beams to the bearing structure by expansion bolts. 12- Anchoring of the beams to uprights by bolted L brackets.
USED ELEMENTS - structural profiles - bolts for coupling - expansion bolts - steel bracket L	
REUSED ELEMENTS - structural profiles UPN	
POSSIBLE VARIATIONS - use of profiles with different section (ipe, hea, heb) - coupling of the vertical up-rights - anchoring beams with up-rights by welding	LEGEND 1- profile UPN 2- steel spacer element 3- bolt for coupling (screw-bolt- metal nog) 4- expansion bolt (bolt with cone plug itted with ring) 5- steel bracket L 6- preesistence

Consolidation of an opening



Horizontal section

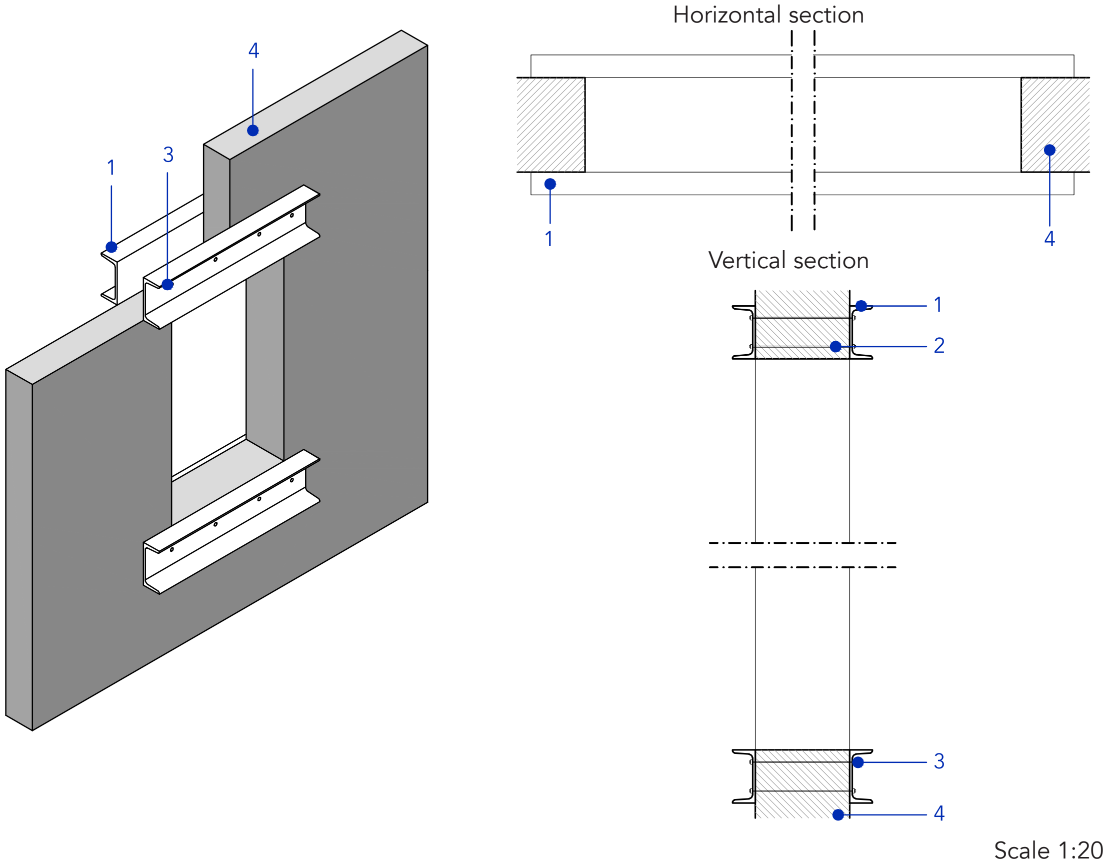
Vertical section



Scale 1:20

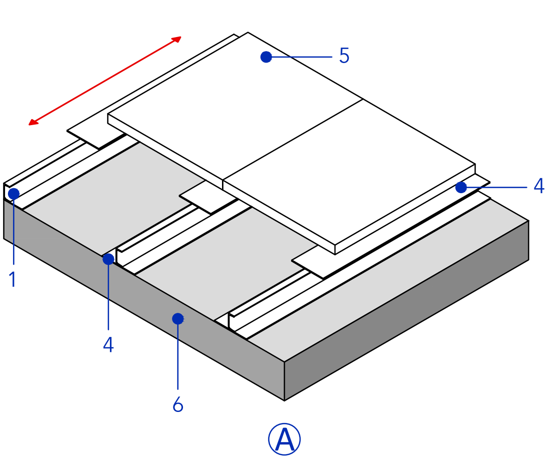
MODE FOR REUSE	
PRE-EXISTENCE - masonry diaphragms - reinforced concrete diaphrams The use with maximum thickness of diaphrams equal to 25 cm is recommended.	WORKING PHASES 0- Cutting of structural profiles, when appropriate sizes are not already available 1- Cleaning of the support and levelling when it is not in flat. 2- Drilling of 4 structural profiles. 3- Installation of mortar/glue on beams. 4- Positioning of beams. 5- Anchoring of beams by expansion bolts to the pre-existence. 6- Installation of the mortar/glue on uprights. 7- Positioning of uprights. 8- Anchoring of uprights by expansion bolts to the pre-existence.
USED ELEMENTS - structural profiles UPN - expansion bolts	
REUSED ELEMENTS - structural profiles UPN	
POSSIBLE VARIATIONS - elimination of bolting between the structural profiles and preesistence - anchoring beams with uprights by bolted brackets L - anchoring beams with uprights by welding	LEGEND 1- profile UPN 2- expansion bolt (bolt with cone plug itted with ring) 3- mortar / glue 4- preesistence

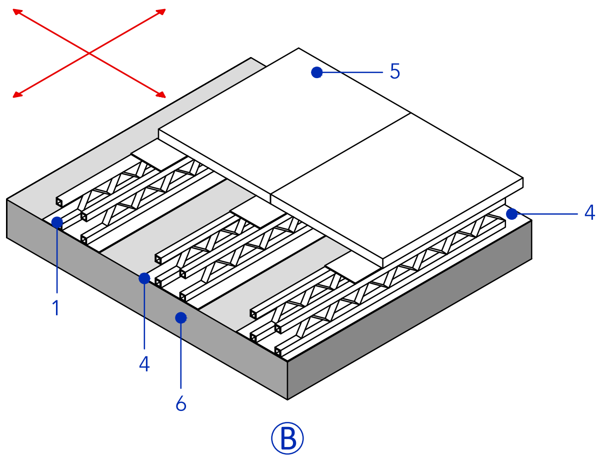
Consolidation of an architrave



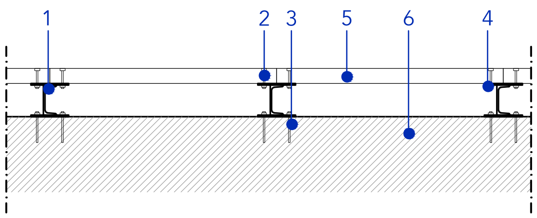
MODE FOR REUSE	
PRE-EXISTENCE - masonry diaphragms - reinforced concrete dia-phrams USED ELEMENTS - structural profiles - bolts for coupling - threaded steel bars REUSED ELEMENTS - structural profiles - threaded steel bars	WORKING PHASES 0- Cutting of structural profiles, when appropriate sizes are not already available. 1- Cleaning of the support and levelling when it is not in flat. 2- Drilling of the wall. 3- Drilling of the beams 4- Positioning of upper beams. 5- Positioning of the threaded rods (upper beams). 6- Tensioning of threaded rods and locking by bolts (upper beams). 7- Positioning of lower beams 8- Positioning of the threaded rods (lower beams). 9- Tensioning of the threaded rods and locking with bolts (lower transoms).
POSSIBLE VARIATIONS - use of distribution plates interposed between the structural profiles and bolts - welding of plates on the bottom of the upper beams and on top of the lower beams	LEGEND 1- profile UPN 2- tie rod (threaded steel bars) 3- bolt for coupling (screw-bolt- metal nog) 4- preesistence

Creation of air space for technical implants

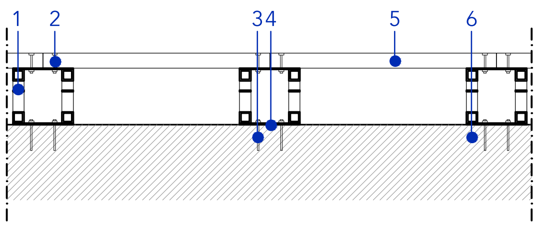




Longitudinal section



Longitudinal section



Scale 1:20

<table>
<tr><th colspan="2">MODE FOR REUSE</th></tr>
<tr><td>PRE-EXISTENCE
- load-bearing part of the floor</td><td rowspan="3">WORKING PHASES
0- Cutting of structural profiles, when appropriate sizes are not already available
1- Cleaning of the support and levelling when it is not in flat.
2- Drilling of steel plates.
3- Welding of the lower plate to structural profile.
4- Welding of the top plate to structural profile.
5- Positioning of profile on the floor.
6- Anchoring of the plates (jointed with the profiles) to the floor by expansion bolts.
7- Anchoring of plates joined with profiles to decking
(the kind of anchoring depends on the constructive characteristics of the decking).</td></tr>
<tr><td>USED ELEMENTS
- structural profiles UPN
- structural truss
- bolts for coupling
- expansion bolts
- steel plates</td></tr>
<tr><td>REUSED ELEMENTS
- structural profiles UPN
- structural truss
- steel plates</td></tr>
<tr><td>POSSIBLE VARIATIONS
- use of profiles with different section (ipe, hea, heb)
- bolting of the profiles of steel plates
- use of wooden elements (sections: cm 5x5, 8x8, 10x5) iin substitution of steel pro-files</td><td>LEGEND
1- profile UPN (A) / truss (B)
2- bolt for coupling (screw-bolt- metal nog)
3- expansion bolt (bolt with cone plug itted with ring)
4- steel plate
5-walking surface
6- preexisting floor</td></tr>
</table>

8.6 _The exogenous reuse

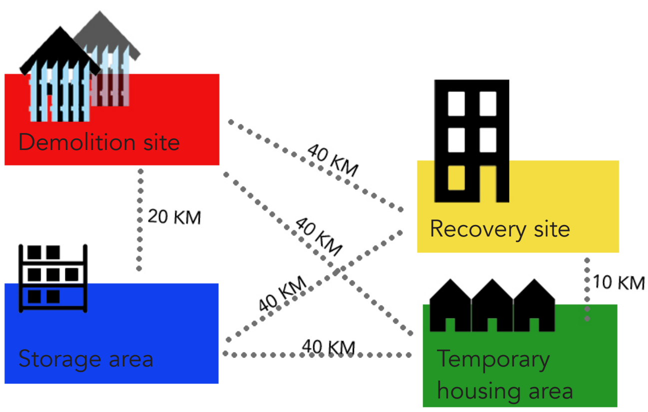
The materials/components coming from the selective demolitions of safety systems can also be reused outside of the construction site, when it cannot find use in the construction site where it takes the disassembly or after already suffering a further life cycle, according to the previous modalities described in the temporary endogenous reuse. They can be reused in the boundary sites for the construction of temporary structures serving the site, for the definition of controlled superfetations in the reconstruction projects or for functions related to community (school, office, residences, etc.) that supplements the effort to overcome the logistical problems connected to the post-earthquake period. In many cases the collapse of the sloping roofs gives way to the underlying flat floors that, after an eventual consolidation, can become the place of controlled superfetations in the head of building, carrying out the function of coverage and, at the same time, of the densification of the building. In other cases, the changing of housing needs or of usage of the building requires a consequent spatial variation with possible volumetric additions, act to satisfy such exigencies. Often the need to make recovery interventions in inhabited buildings creates problems related to the rapidity of execution in view of the logistical difficulties of users in them located, which, during the realisation of the intervention, are without a house. In addition, these problems can be resolved through the construction of temporary accommodations near the building object of intervention, whose components come from the selective boundary demolitions integrated by the local supply chain.

Methodological operatve innovation in the reconstruction

Often the enterprises, due to emergencies, perform contemporary interventions of a different nature. The enterprises make partial and/or total demolitions of buildings that have considerable structural impairment, which therefore results in additional safety installation and makes recoveries of buildings that do not present structural problems, despite being in poor maintenance condition and they are inhabited. While in the first case, the preliminary organisation of the works does not care about problems related to the inhabitants/users, as their shelter was the object of intervention in the first post-emergency phase (project C.A.S.E. M.A.P.). In the second case, it also must be taken into account that the shelter of the inhabitants or the moving of the functions (offices/ business) that are present in the building for the whole duration of the intervention. It is necessary to take into account that the city of L'Aquila, for known reasons to date, presents a low receptivity and consequently, the logistics management of these interventions results difficulty and they become fragmented at the end of the long-life. When it is possible to create the conditions for temporarily moving residents, the necessity of short-time realization of recovery interventions affects the quality not so much of the works, but rather the attention of sorting and separation of waste materials, with a negative impact on the global sustainability of the intervention. It is also necessary to underline that the recovery interventions on inhabited buildings presuppose a temporary shelter for the users, therefore, for a limited period, but which must also respond to specific standards of environmental comfort, especially when the interventions are carried out during the winter, where in L'Aquila a harsh climate is present.

Therefore, an operative-methodological process that incentives the reuse of the materials deriving from the selective demolitions (partial/total) in the neighbouring recovery reconstruction sites is proposed, with the aim to build temporary accommodations acting to host the users of the buildings to recover, during the period in which the recovery operations take place. In this way, it will be possible both to overcome the problems related to the low receptivity of the city of L'Aquila, ensuring temporary accommodations with environmental comfort comparable to that of stable structures and to encourage a sustainable operation of recovery with timelines that facilitate a careful handling of the waste materials. The materials/components that derive from partial or total selective demolitions of the buildings that present structural problems, when they are not reused within the site, can be partly transported to the recovery neighbouring site and partly transported to the temporary storage. The portion that is transported to the recovery neighbouring sites, in addition to being subjected to quality controls, must be selected (typology and performance) and quantified according to the site demands (such as according to the type of works that will executed) and according to the number of housing units that are necessary to host the users of the building that must be recovered. Therefore, conceptually, 4 areas are present: the demolition site, the temporary storage area, the recovery site and the temporary housing area.

The temporary storage area can, in specific conditions or for a portion, coincide with the storage area of the recovery site. For what concerns the distances, it is believed that the sites of selective demolition (and/or the temporary storage) should not be a distance more than 40 km from the recovery sites. The temporary housing area must preferably neighbour the recovery site. If the immediate neighbouring of the temporary structures to the recovery site condition cannot be not met due to security concerns or an overall lack of area, it is believed that the maximum distance between the housing temporary area and the recovery site must be at most 10 km.



Such an approach requires careful planning with the aim to simultaneously manage the selective deconstruction of a building, not only on the base of the constructive characteristics of the building itself, but especially on applications in terms of typology and quantity of materials/components of the recovery site.
The system becomes an integral part of the input and output of the local supply chain. In fact, although the objective is that of building temporary accommodations with waste materials, if it does occur, the indispensability of a portion of them, due to the boundary conditions, the local supply chains can bypass it. At the same time, when the recovery operations of the building will be finished, the residents will return to live in it and the temporary housing units could be assembled and disassembled in a recovery neighbouring site (if they still have enough residual performance), or the materials/components that constituted them could be reused for the recovery of another building or inserted in the supply chain of local industry. In light of the poor state of repair of Italian building heritage, the operative-methodological proposed lines assume validity at national level, encouraging local closed cycles that transform the selective demolition of a building in the "mine" for the building regeneration of a building adjacent to it, with evident environmental and economic advantages, while stating that the assumption of feasibility of such a method is the integration and coordination between demolition and construction.

Case study: demolition and reconstruction of post-war buildings in L'Aquila.

It is proposed the feasibility study of a total selective demolition and of a neighbouring recovery intervention, in reference to two buildings in the territory of L'Aquila, located in the some continuous medium-dense residential area. In case of the recovery building, it is proposed to organise a residential area to act as host for the users during the reconstruction operations. Temporary modules realised with materials deriving from the neighbouring selective demolition from it.
It is assumed that the earthquake has irreparably damaged one of these buildings, herein after referred as building A. It is not fit for the use and it has been made safe with shoring operations of support of floors by a multi-com system integrated with a tube-clamp system and wooden plank of load redistribution and an operation of lateral rods constrained implemented by means of coupled beams, UPN 160 and steel rods, with wooden plank of load redistribution.
The second building, hereinafter referred as building B, has not been damaged after the earthquake. It is usable, but it needs a recovery intervention aimed to increase energy efficiency with implant replacement and to upgrade the internal distribution of the building.
With the aim to describe a generic case easily applicable to specific cases and to simplify the description of the procedural process, it is hypothesised that the building A

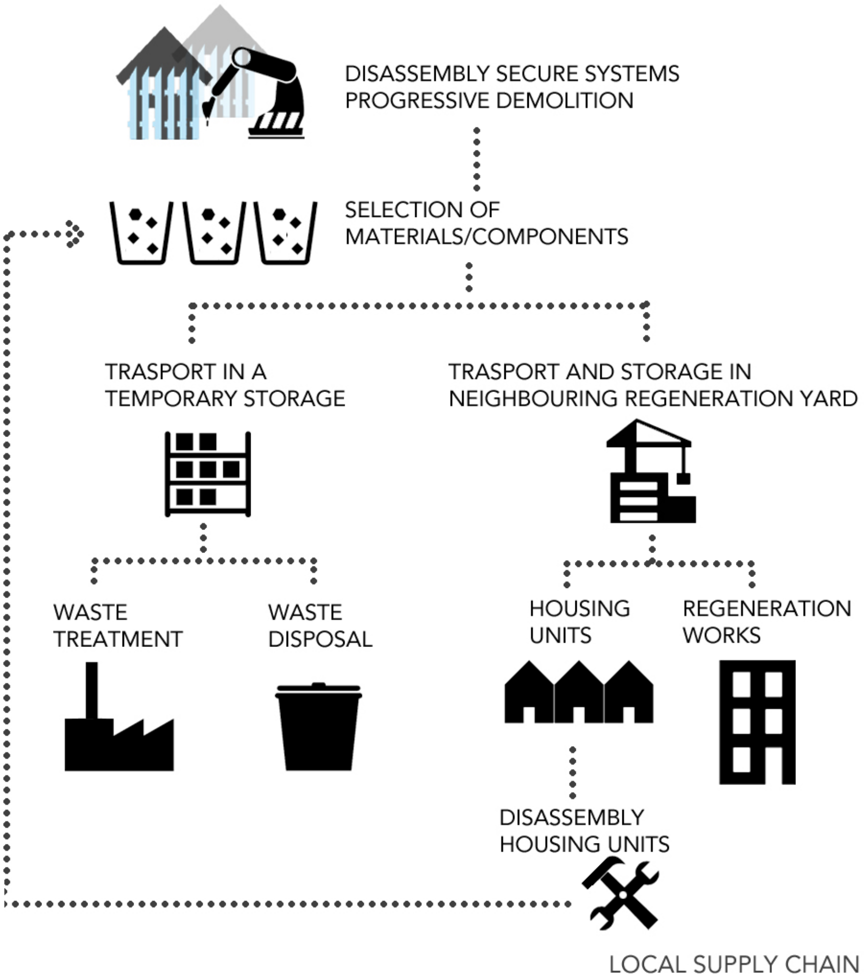
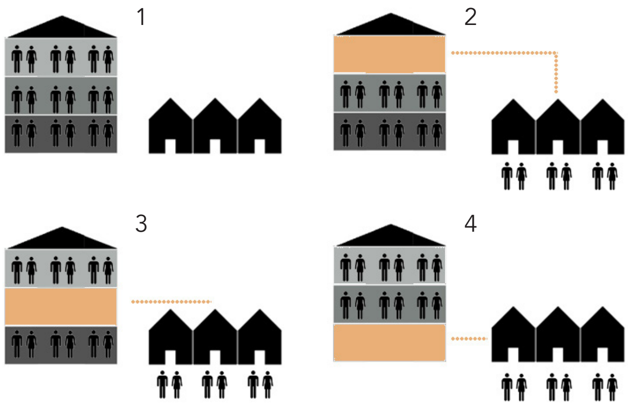
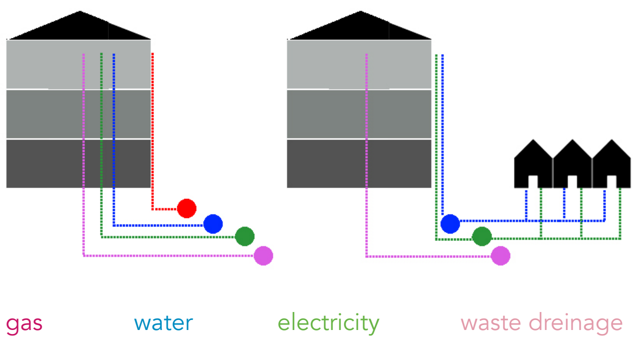


Fig. 25 _ Methodological-operative innovation: hypothesis of exogenous reuse

and B are identical and that the spatial conditions for an easy organisation of the site in terms of materials storage, handling machinery and predisposition of equipped areas (area for temporary accommodations as explained below) are present.
The buildings were built in 1970, they have a planimetric footprint of about 250 sqm, 3 aboveground floors that each house 3 apartments, have the pitched roof and present the following constructive equipment. The bearing structure is in reiforced concrete with hollow block floors and foundations with reversed beams. The lower horizontal closures are constituted of paving in stone (1.5 cm), mortar (2 cm), lightweight concrete screed (6 cm), concrete slab (6 cm), hollow block floor (20 cm) and plaster (2 cm). The horizontal top closures are made of tiles on wooden rafters, waterproofed sheath (0.4 cm), concrete slab (6cm), hollow block floor (20 cm) and plaster (2 cm). The vertical closures are made with inner plaster (2 cm), hollow bricks (8 cm), airspace (5 cm), hollow bricks (25 cm), outer plaster (2 cm) and with wooden windows. The internal partition elements are made with hollow bricks. The buildings are equipped with autonomous systems for the production of hot water and heating with a natural gas boiler and cast iron radiators.
It is specified that the data related to the constructive equipment, in such cases considered known, must be obtained through careful preliminary investigations, which is composed both of the examination and the analysis of all the documents present in the public archives in carrying out destructive tests on time.
The empty for full volume of the building A is equal to about 3000 mc. Therefore, the weight of rubble deriving from the demolitions is equal to about 1720 tons[42].
In function of such value, of the building characteristics, also using the percentage data of incidence of the single matter homogeneous fractions on the rubble produced until today, it was possible to dimension the areas for sorting and stocking of materials during the demolition, with the aim to establish appropriate organisation of the site.
For the definition of the site organisation of the building B, the same method was used. For what concerns the building B, it was necessary to provide temporary accommodations acting to host the residents for the necessary time for the operations of partial selective demolitions and of energy efficiencies. Specifically, the planed works consist of the demolition of interior partitions and in making over of wooden partitions, in making over the electrical, water and heating system (including the replacement of boilers), in making over the drain lines, in the replacement of the portion of the tiles facing south with photovoltaic tiles, in the assembly of the related implant, in the replacement of windows and thermal insulation of the envelope.
The interventions on building B must be followed proceeding from the highest floor to the lowest floor.
In the site area, a temporary warehouse must be set up to store the furniture of the apartments where the works must be carried out.
The area that hosts the temporary housing units is adjacent to the construction site area of the building in order to allow progressive moving to the temporary accommodations. The first phase consists of the transfer of the residents from the highest floor, such as the second floor, into the temporary accommodations. Once finished the works at the second floor, the residents of the second floor can return in their apartments and the residents of the first floor can transfer themselves into the temporary accommodations, then return to their apartments once the works are finished. In the some way, it will proceed with the ground floor. A temporary unit for each apartment floor present must be built. Therefore, in such case 3 temporary housing units must be built. It is therefore evident that it is necessary to plan and to coordinate together 3 interventions: the total demolition of building A, the assembly/disassembly of the housing modules, the partial demolition and the energy efficiency interventions of building B.



Considering the fact that two-thirds of the inhabitants always remain inside the building during the work, it is necessary to actively maintain all the services (gas, electricity, etc.). Considering the fact that the replacement of the technological implants must be carried out, the water and electrical systems can be moved outside of the building.
Once made, the interception of the water and electrical grids from the main line, they are connected with the provisional housing modules. This ensures the supply of water and electricity to the housing units when the systems of rainwater collection or the photovoltaic panels cannot meet the demands of users. In the same way, the surplus of electricity produced by photovoltaic panels of the temporary units can be used for the benefit of the site.
For what concerns the drain lines, running toward gravity, it is possible to replace parts of the horisontal branch and of the columns from the top or maintain the existing



lines during the work while simultaneously preparing new drain lines to be put in use after finishing the recovery intervention. In the illustrated case study, the existing drain lines are maintained in the original position and replaced for parts. The lines of methane gas can be removed for the benefit of a more sustainable solution, such as heating and hot water systems powered by a wooden pellet boiler and electric induction cooktops. The removal of such a line must be carried out between the first works for safety reasons; therefore, for the entire duration of the construction site, the residents (for two- thirds present inside the building) must use electric induction cooking systems.

In the time schedule of the works for building A, the following phases are considered: preliminary investigation of the building (analysis of the documentation and punctual destructive tests, definition of the characteristics of the place and the surrounding area), organisation of the construction site, disassembly of bathroom fixtures and separation of taps and fittings, disassembly of plumbing works, demolition of tiles in kitchens and bathrooms, disassembly of interior doors with separation of the subframe, frame, handles and hinges, disassembly of the windows, sills, boilers, radiators, plates of switches, baseboard, removal of the electrical system, removal of coating of the ladder. In the roof, it provides for the removal of the tiles and of the underlying wooden elements, removal of the sheath, demolition of screed and concrete slab, demolition of the hollow floor bricks, removal of the joists. In the second, first and ground floor it provides to easing of tension of cables of tie-rods, to the cut and removal of the UPN profiles to the height of the floors, to the scrape of plaster and to the demolition of the internal and external walls, to the demolition of paving and substrate bedding, to the demolition of the lightweight screed, to the cut and removal of the water and exhaust piping, to the disassembly of the shoring that support the floor, to the demolition of the hollow floor bricks and removal of the joists. In the end, it provides for the demolition of the beams and of the pillars in reinforced concrete and of the ladder, to the excavation along the perimeter of the building and to the demolition of foundations.

In the time schedule of the assembly of the temporary housing units the following phases are considered: predisposition of the area and organisation of the construction site, transportation in the area of materials/components deriving from the demolition of building A (tube- clamp system, multidirectional system, wooden planks, profiles UPN), transportation in the area of materials/components deriving from the local supply chain, connection of the water and electrical grid to the main grid, assembly bearing structure (multidirectional system, reticular truss), assembly gabion wall filled with rubble, positioning punctual foundations, assembly block of implants/services/connectives, assembly living module and sleeping module, connections of the implants, assembly of the coverage (tube-clamp system and corrugated sheet), assembly photovoltaic panels and solar thermal panels, assembly duct and connection with the tank of rainwater harvesting, assembly finishes, connection to water and electrical grid, external arrangement and assembly furnishings.

In the time schedule of recovery works of building B the following phases are considered: preliminary investigation of the building (analysis of the documentation and punctual destructive tests, definition of the characteristics of the place and the surrounding area), organisation of the construction site, disassembly of external line of the natural gas implant, interception of water and electrical grid on the main grid and repositioning outside the building with connection to the individual floors and to temporary housing units, replacing natural gas boilers with wooden pellet boilers, starting from the upper floor, for each floor it provides to the disassembly and stacking of the furniture, disassembly of bathroom fixture and separation of taps, demolition of tiles in kitchen and bathroom, disassembly of interior doors and windows, disassembly of radiators, plates of switches, baseboard, removal electrical system, scrape of plaster of internal partitions, demolition of paving and substrate bedding, demolition of the lightweight concrete screed with cut and removal of the water piping, demolition of internal walls, removal and subsequent restore of the drain pipes related to the floor, installation of water system and internal partitions, installation of insulation in the vertical infills, finishing of internal wall, installation of screed for implants, thermal-acoustic insulation, installation of radiant panels, installation of paving, baseboard, plates of switches, fixtures, installation of bathroom fixture and furniture. On the whole building, it provides to scrape the existing plaster and to install thermal plaster and paint. In the roof, it provides for the removal of the tiles and the underlying rafters, removal of the sheath, installation of insulation and waterproof sheath, with subsequent assembly of the tiles and replacement of a portion of them with photovoltaic tiles and assembly of a relative implant.

The work mode to floors in the recovery intervention of building B and, consequently, the progressive transfer of the residents in the housing units, involves the inability of carrying out interventions concurrently on all floors and needs of additional security measures.

With the aim of providing a basis of comparison, while remaining unchanged the considerations on building A and the evaluations in reference to the installations of building B, it has defined a second hypothesis that considers the concurrent transfer of all inhabitants in the adjacent, temporary housing unit. In this case, 9 temporary housing units must be prepared.

By comparison of work program in reference to 2 hypotheses made for building B, the hypothesis in which all inhabitants are transferred contemporarily in the temporary housing units presents execution times equal to 13% lower than the hypothesis in which the inhabitants are transferred in the temporary units by floors.

However, if we consider globally the time for the works to carry out in building B and the necessary time for the assembly of temporary modules, the two hypotheses provide equal execution times. In fact, the most time due to enforcement of the work for floors and the additional security measures (in cases in which the residents are transferred by floors) is offset by the required time to build a greater number of temporary housing units.

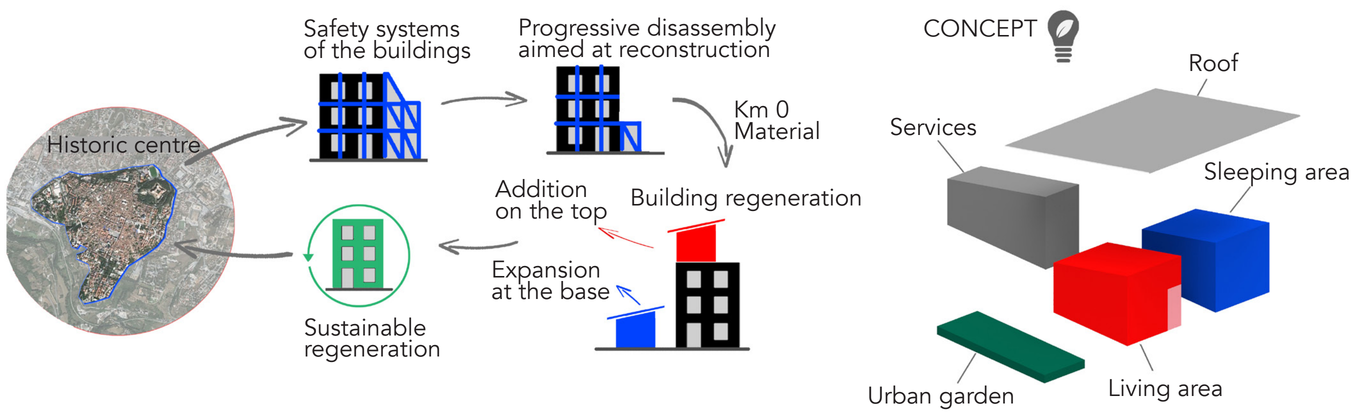
In fact, if we consider globally the time for the works to carry out in building B, the necessary time for the assembly of temporary modules and the necessary time for the disassembly of the latter, the hypothesis in which the inhabitants are transferred by floors in the temporary units presents execution times equal to 14% lower than the case in which all residents are contemporarily transferred in the temporary units.
In the illustrated case, the time for assembly and disassembly of a greater number of housing units is greater than the additional time necessary for the execution of works to floors.

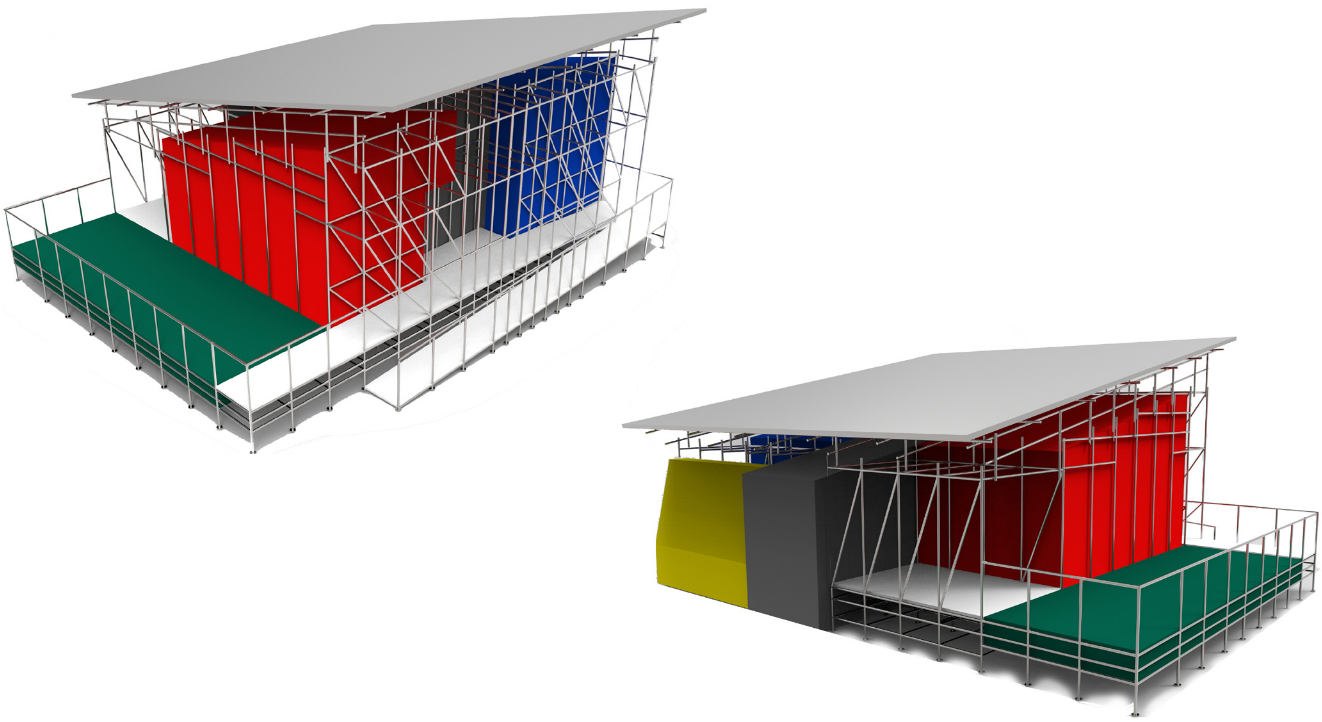
Feasibility study of a temporary housing unit
In the field of exogenous reuse, the proposed study has as object the definition of housing unit, aimed to the temporary usage a period of average time, variable from a few months to a few years.
The housing unit is used to respond to a housing demand consequent to the interventions of recovery/regeneration of buildings, but for their own specificities, such systems may be used in all situations that provide for a period of average time, such as recovery for workers in traveling sites, hosting social indigent categories or students/workers to respond to the housing demand post-emergency. In the end, in a perspective of reversibility the units can be used for the definition of controlled accretions in head of buildings.
The sustainability of the housing unit proposed is strongly linked to the territory and to the use of materials derived from the local supply chain. The system moves away from the concept of temporary as "possible everywhere and in every circumstance" and approaches the concept of "local temporariness", meaning that the system is sustainably compatible with the classification described above with in a predetermined radius mileage from the place of procurement of the material, such as cases in the territory of L'Aquila. From a constructive point of view, the system is potentially assembled everywhere, but underlying the conditioning of the territory of L'Aquila (and of the historical moment that it faces) on the design, technological and material choices, using this housing unit in another place would be incongruous. Besides, the impact of the transportation would increase and the level of global sustainability would decrease. The *ratio* and the operative-methodological process ingrained to this project can be repeated in other places. For example, in a different place from that considered the tube-clamp system could not arise from disassembly, but from local building enterprises, limiting in such way the impact of transportation and the reuse of materials derived from local cycles.
The temporary housing unit responds to the requirements described below.

- Flexibility. It is ensured by the modularity of the system, the international basic module 1M=10 cm was chosen as a reference; in function of the number of inhabitants, the housing unit can suffer some modular variations in elevation and in length, keeping, instead, constant the width dimension. The modularity also allows coordinating the available materials, which in most cases derive from industrial processes (tube-clamp system, multi-com system, UPN profiles, bridge plank, wooden elements etc.) with the materials derived from the local supply chain, including serial industrial processes and limiting, in such a way, the scraps in the definition of the building system.
- Reversibility. All the elements that constituted the construction equipment are dry assembled. The ground attack is punctual, the bearing structure in multidirectional system rests on the ground through base plates of the old system, which can eventually be integrated with screw piles foundations. The central block is placed on prefabricated foundations in reinforced concrete or alternately on coupled beams UPN 220 coupled arranged longitudinally and transversely wind braced with beams UPN 180 (in function of the features of the support plan).
- Rapidity of assembly/disassembly. The elements are dry assembled by reversible connections (bolting and nailing). The bearing structure is constituted by multicom systems with tubes and clamps that born as temporary for the site services and are, therefore, mountable and removable in short time and with extreme ease. The structure of the block services is, instead, constituted by system of beams and pillars made with UPN profiles bolted by brackets.
- Environmental comfort. The lighting comfort is ensured by the control of the natural light, the unit is placed longitudinally facing south. The overhang of the coverage and the volumetric displacement of the block of services shield the living area and the sleeping area from summer irradiation, controlling the lighting and ensuring thermal advantages. In case of added in the area near the building, the sleeping area is shielded also by the gabion wall that leaves to penetrate only a portion of the solar rays, ensuring lighting, but limiting overheating. The thermo-hygrometric comfort is also pursued thanks to the control of the natural ventilation: the opening have been positioned in function of the strength and the speed of prevailing winds. The module is protected by the prevailing wind (north-west direction) through the service block in the living area and the closure of the west face in the sleeping area. In case of added in an area near the building, the gabion wall contributes to comfort in the sleeping area, being placed transversely to prevailing wind. In addition, the winter dispersions are limited thanks to low index of compactness and to an efficient design of the housing that present insulation suitable to the weather in L'Aquila.
- Transportability. The unit is constituted by a kit of elements that is assembled on the construction site. Therefore, they are easily transportable. The weight of the module in the solution on the roof of the building is equal to about 25 tons, while the weight of the module in the solution area near the building is equal to about 50 tons. Half of the weight is constituted by the module and by its structure, and the other half by the gabion wall. Thanks to a careful design of the building equipment, it is possible to carry out stand-

ard transportation. The block of services can be built on the construction site or it can be transported, assembled in part, which presents suitable dimensions for standard transportation.

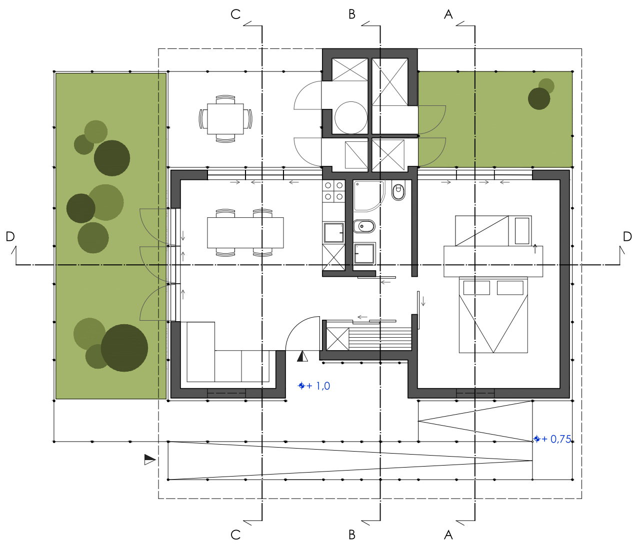
- Self-sufficiency of technical implants. The housing unit can ensure for a limited period, a self-sufficiency of technical implants, by being provided with systems of production of electrical energy and heating from solar, storage and of purification of rain water, treatment of grey water and composting of the black water. The system can also be linked to the technical grids (water, electricity, etc.). In this way, it is possible to use the module on the roof of the building connecting it with the grids of the building and, at the same time, to use the module in an area near the building without the burden of the connection to the technical grids.
- Economic accessibility. The module is constituted almost entirely by reused materials that, to date, represents a waste and, thus, it has a zero cost. The only costs are related to the technical implants, insulation, and the connections (screws, bolts, brackets, etc.).
- Innovation. The module is strongly innovative for technological and technical implants. Constructive systems that are born from the site needs (consequently temporary) have been used, giving to them a new use modality that enhances the flexibility and the reversibility. Through the design of vertical and horizontal closures made of wooden reused elements and sheep wool insulation, the environmental comfort was ensured. The module combines the advantages of the temporariness and those of stability and turns them into innovation.
- Sustainability. The reversibility, the flexibility, the using of energy renewable sources, the attention to environmental comfort and to the life cycle of materials, the rain water harvesting, and the efficiency of the implants make this temporary module environmentally sustainable.

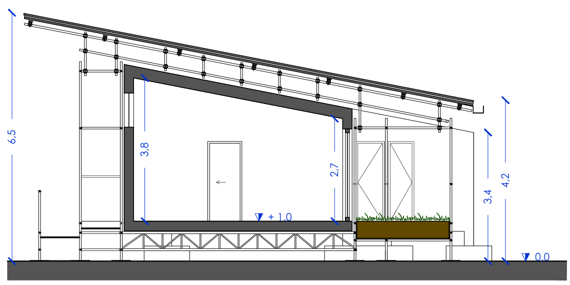




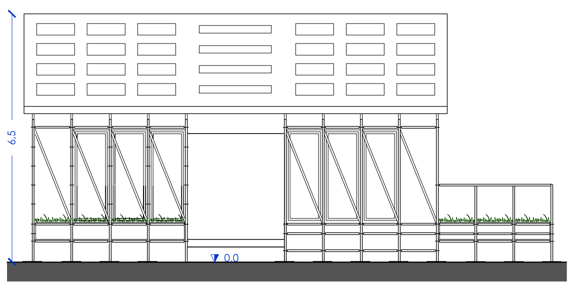
Project solution 1
Addition on the top of the building

Plan 1,2 m

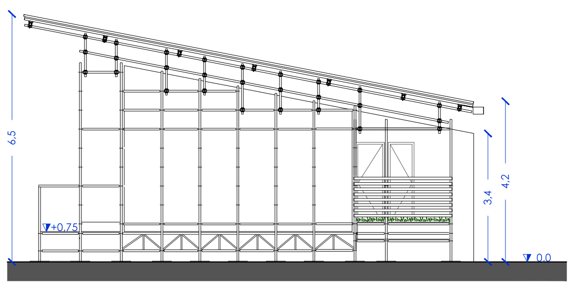




Section A-A_ project solution 1



South elevation_ project solution 1

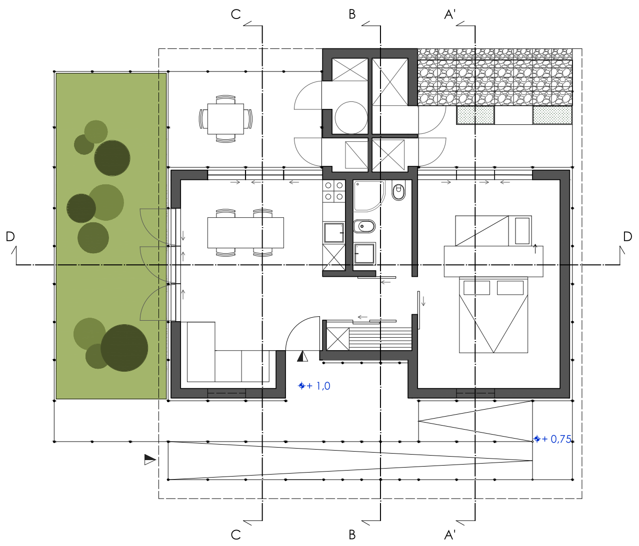


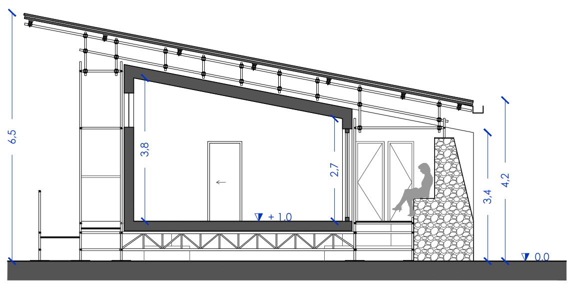
West elevation _ project solution 1

Project solution 2
Expansion at the base of the building

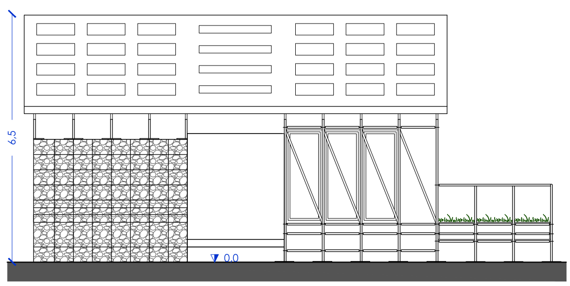
Plan 1,2 m

N

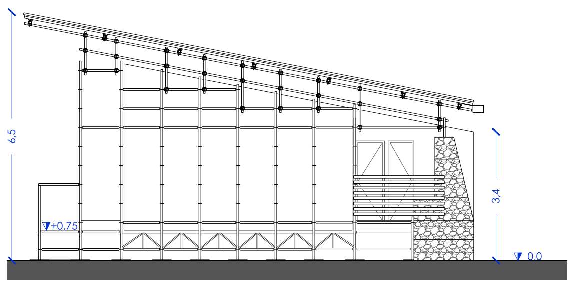




Section A'-A'_ project solution 2

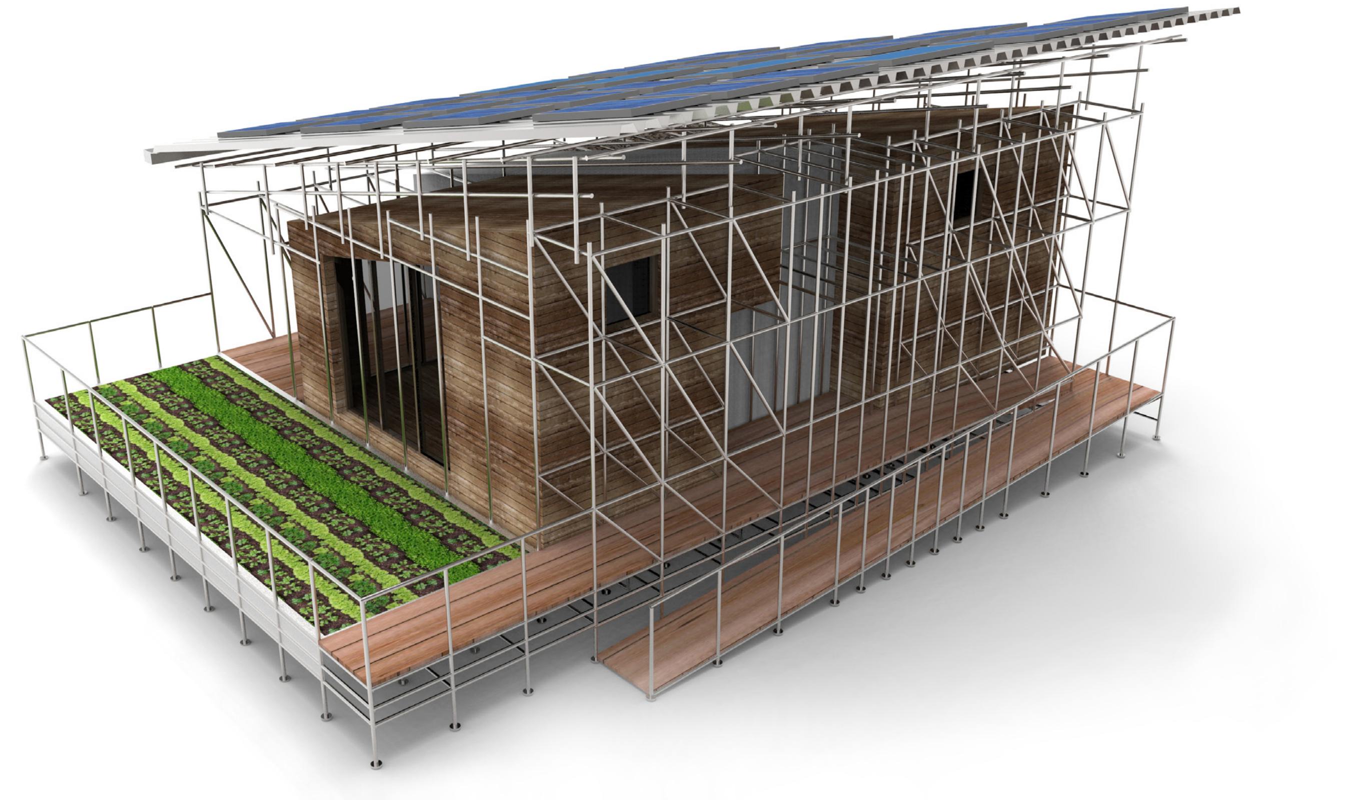


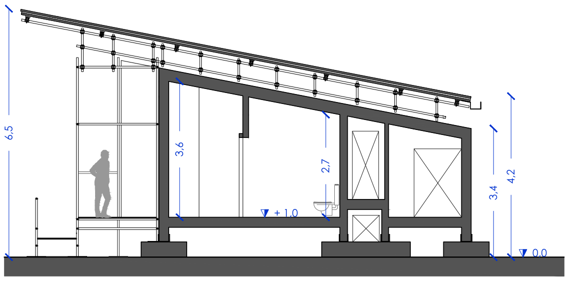
South elevation_ project solution 2



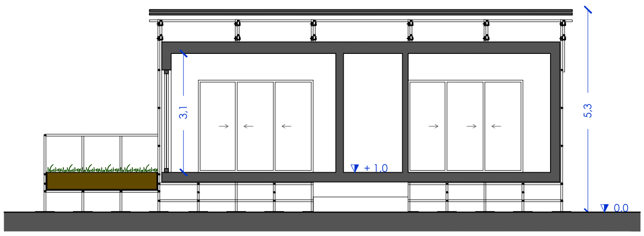
West elevation_ project solution 2

scale 1:200

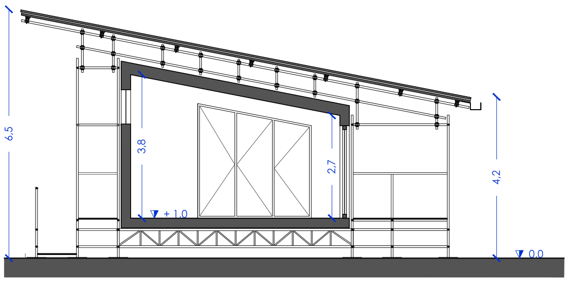




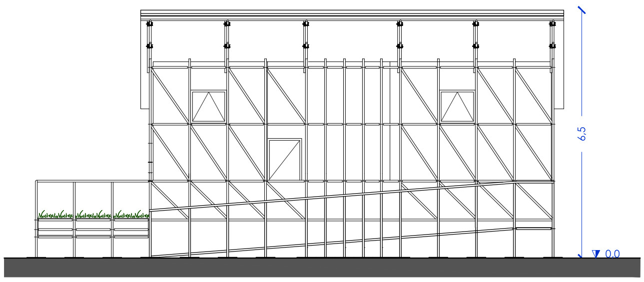
Section B-B_ project solution 1 and 2



Section D-D_ project solution 1 and 2

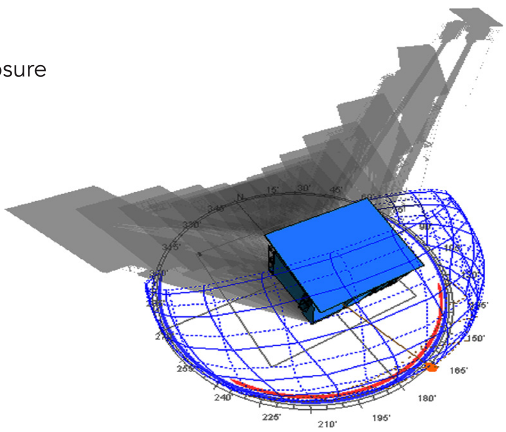


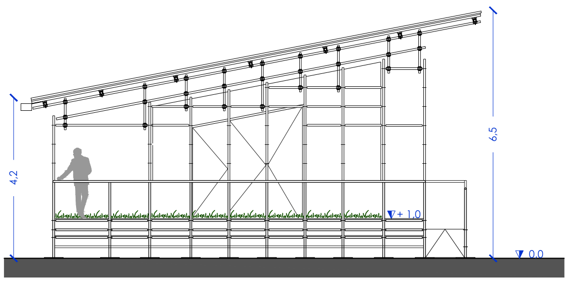
Section C-C_ project solution 1 and 2



North elevation_ project solution 1 and 2

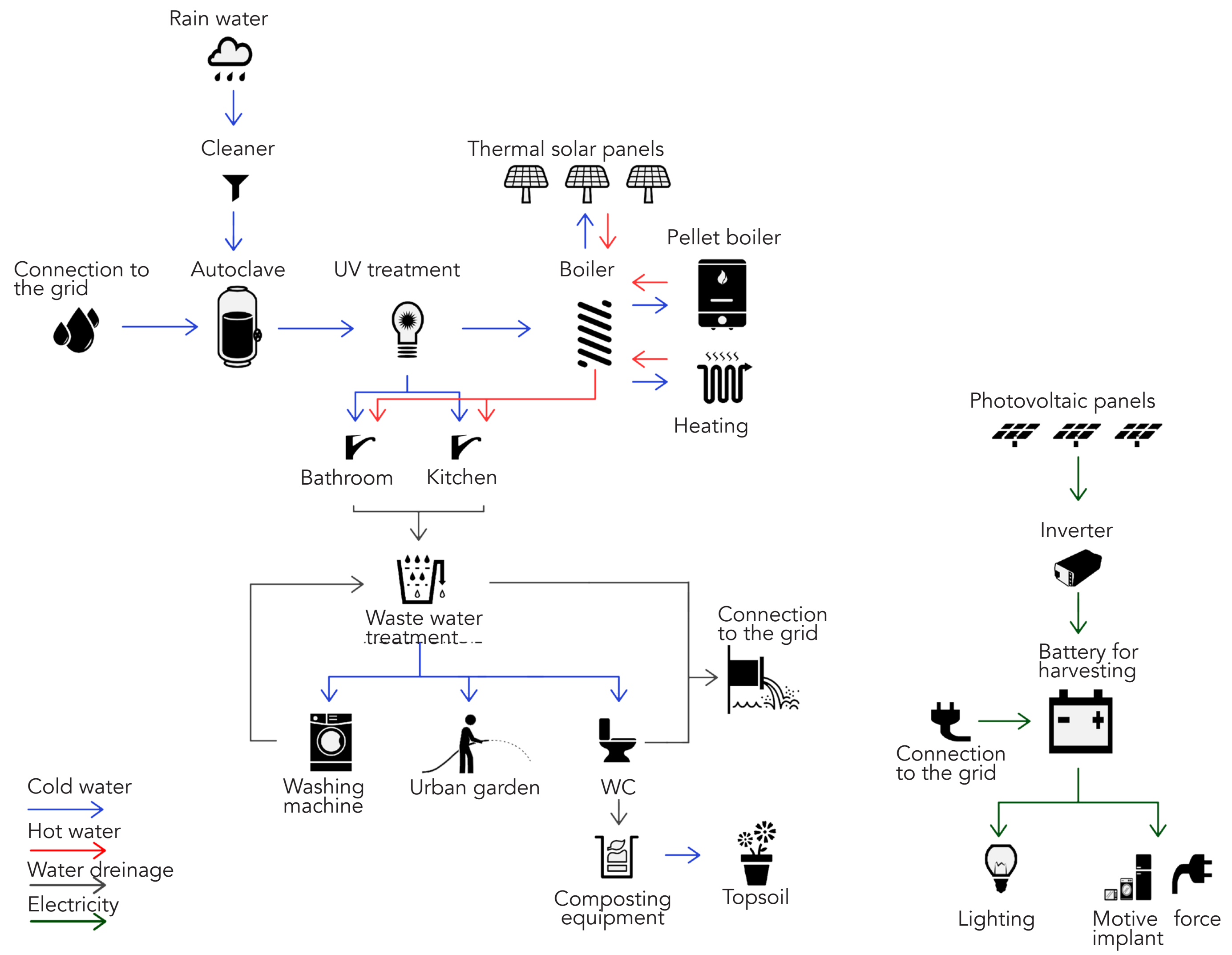
Exposure

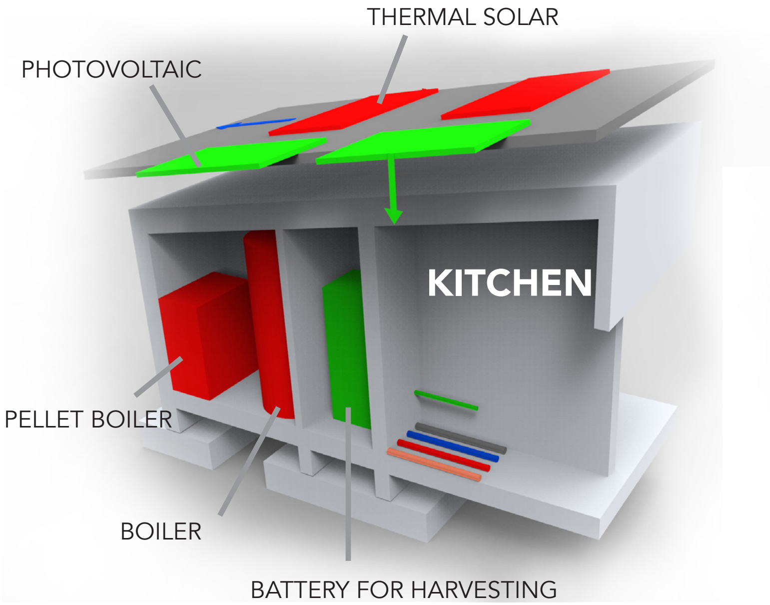


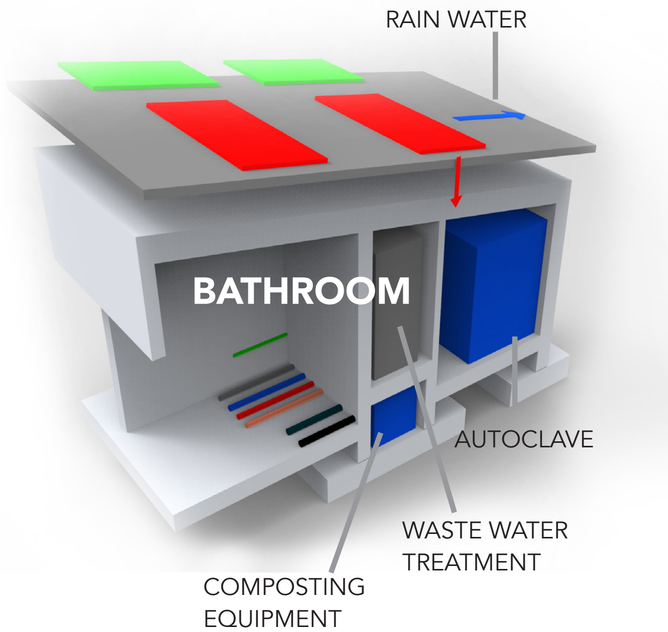


East elevation_ project solution 1 and 2

FUNCTIONING OF THE TECHNICAL IMPLANTS

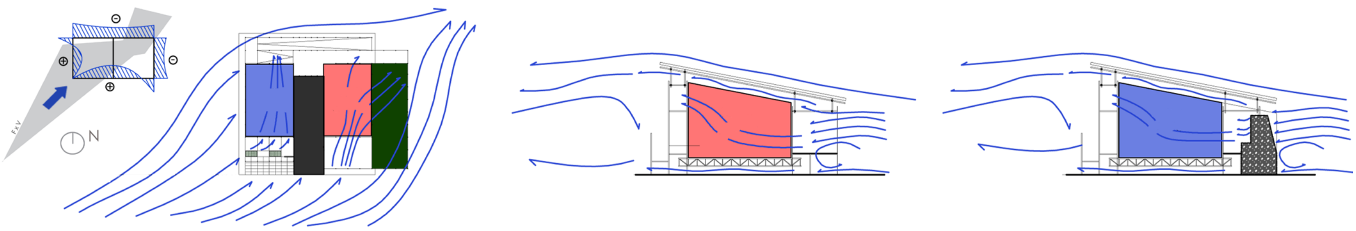




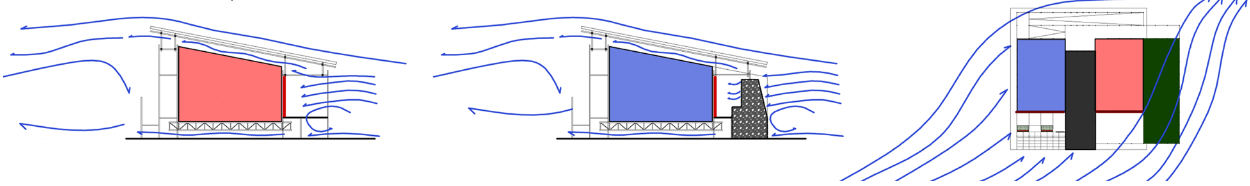


NATURAL VENTILATION

Summer operating



Winter operating



RAIN WATER

Rainfall in L'Aquila (mm)

G	F	M	A	M	G	L	A	S	O	N	D	TOT.
87,0	43,6	49,0	21,8	27,4	56,2	9,0	48,0	33,2	128,4	61,0	28,6	593,2

Annale idrogeologico 2003

Individual consumption
200 liters/day
6 mc/ month

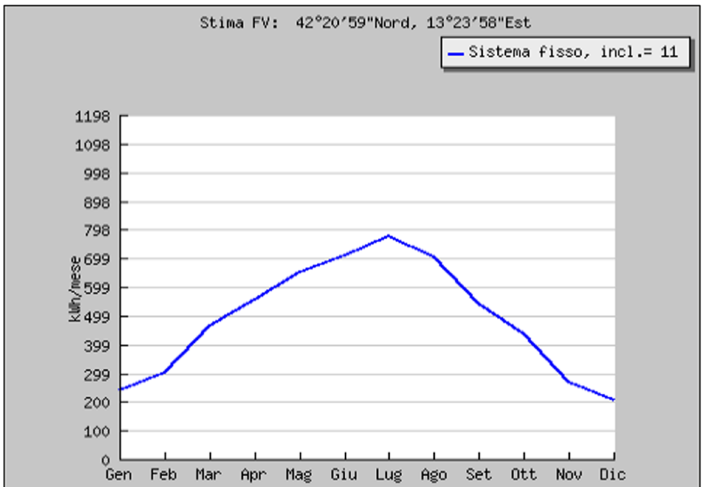
Water collected on the roof (mc)

G	F	M	A	M	G	L	A	S	O	N	D	TOT.
13,05	6,54	7,35	3,27	4,11	8,43	1,35	7,2	4,98	19,26	9,15	4,29	88,98

The rainwater collected on the roof annually meets n. 1 user.

PHOTOVOLTAIC

Total annual demand: 3600 KWh/year
Peak power of a panel: 208 W
Number of panels on the roof: 24

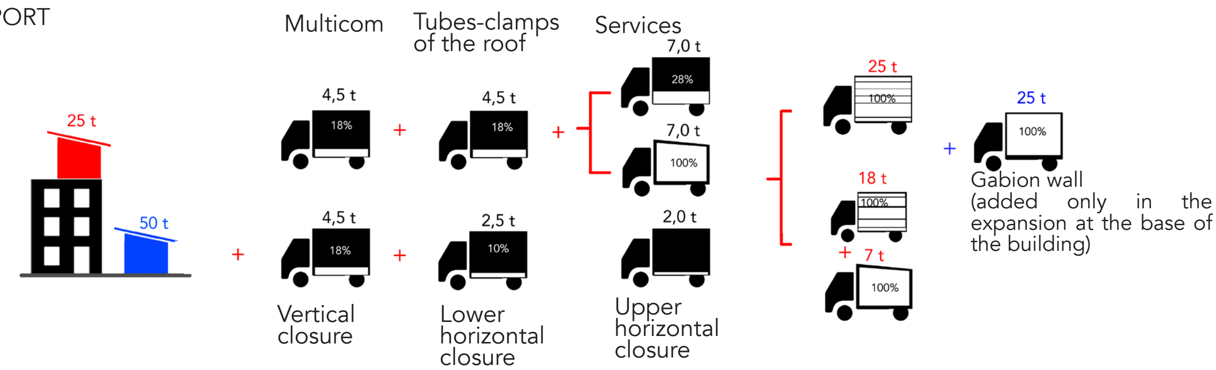


The system produces a surplus of energy equal to 5850 kWh/year.

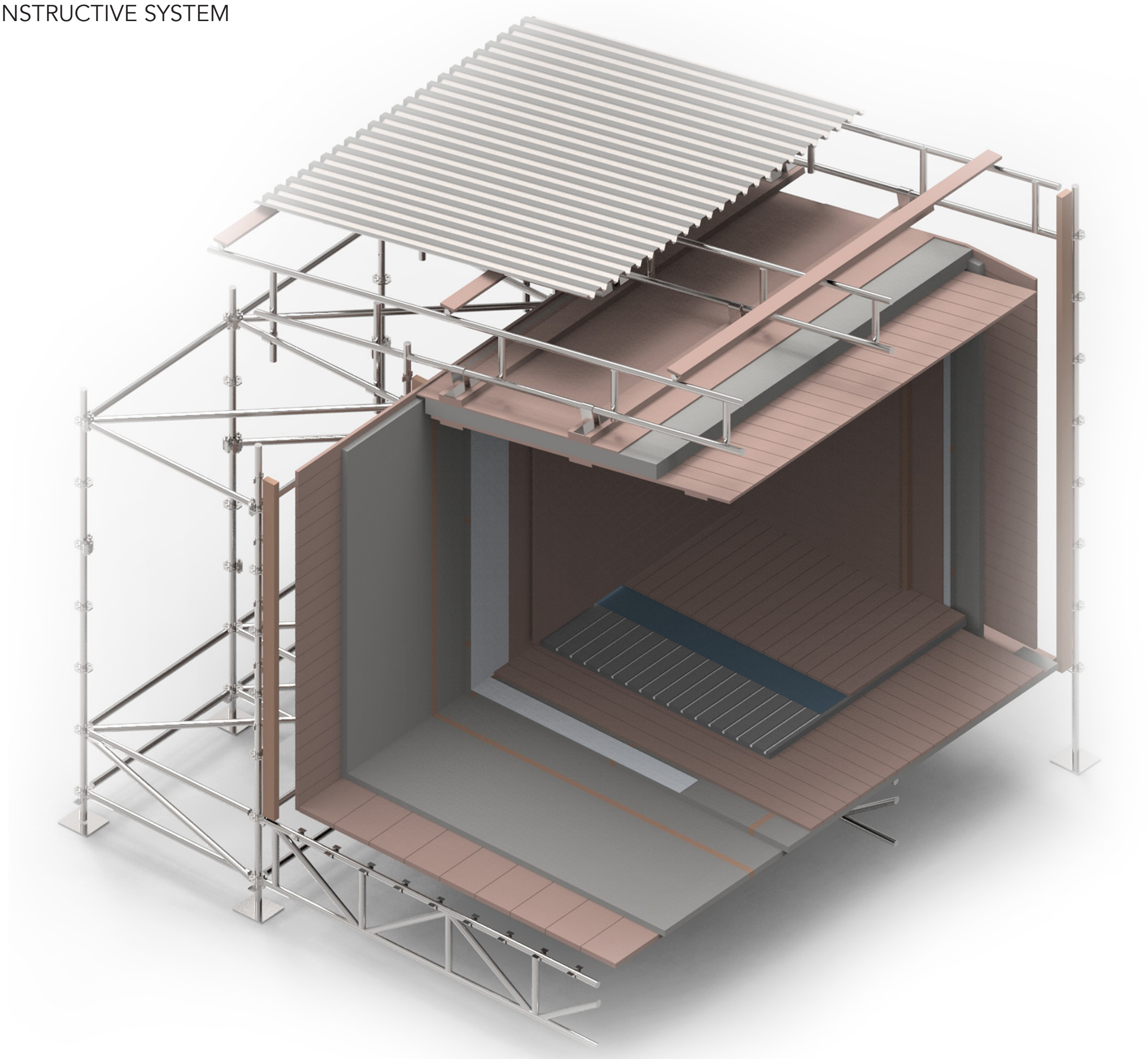
http://re.jrc.ec.europa.eu/pvgis

Sistema fisso: inclinazione=11°, orientamento=0°				
Mese	E_d	E_m	H_d	H_m
Gen	7.70	239	1.96	60.8
Feb	10.70	300	2.74	76.7
Mar	14.90	463	3.95	123
Apr	18.50	554	5.03	151
Mag	21.00	650	5.92	184
Giu	23.70	710	6.81	204
Lug	25.10	777	7.31	227
Ago	22.70	704	6.60	205
Set	18.00	540	5.02	151
Ott	14.10	438	3.81	118
Nov	9.02	271	2.35	70.4
Dic	6.66	206	1.71	52.9
Media annuale	**16.0**	**488**	**4.44**	**135**
Totale per l'anno		**5850**		**1620**

TRASPORT



CONSTRUCTIVE SYSTEM

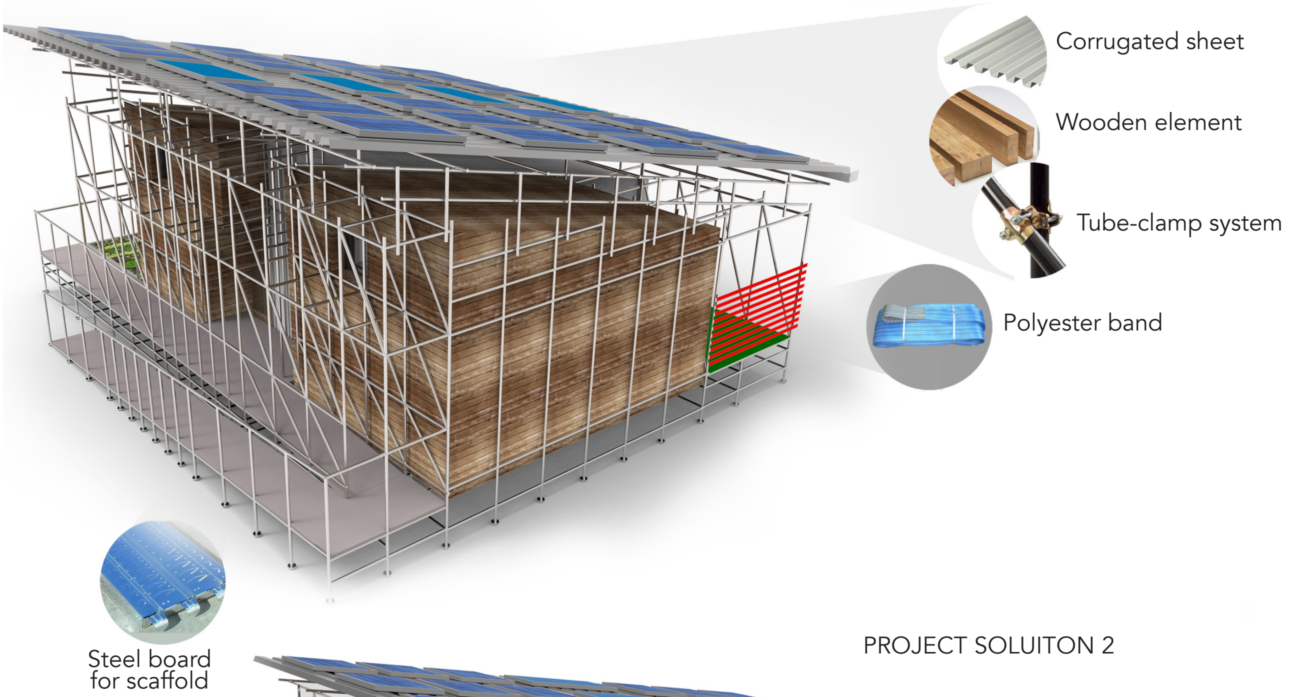


LOWER HORIZONTAL CLOSURE
1- Wooden board 120 x25 mm
2- Pipe of floor heating, 16 mm
3- Soundproofing panel, wax paper 2 mm
4- Wood fiber panel 50 mm
5- Wooden element 50x50 mm
6- Vapour barrier
7- Sheep wool insulation 50 mm
8- Wooden board for scaffold 300x40 mm
9- Omega steel profile
10- Multicom truss

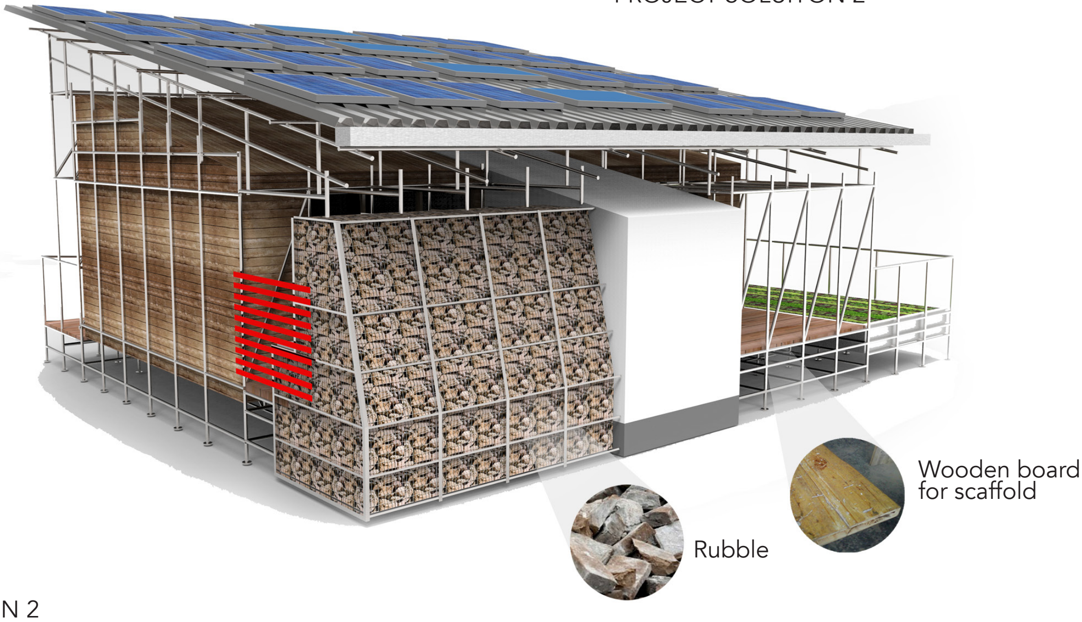
VERTICAL CLOSURE
1- Multidirectional system
2- Wooden upright 100x50 mm
3- Steel eyelet for anchoring
4- Wooden board 120x25 mm
5- Sheep wool insulation 50 mm
6- Wooden element 50 mm
7- Vapour barrier
8- OSB panel 12,5 mm
9- Air space for implants 50 mm
10- Windows with double glazing

UPPER HORIZONTAL CLOSURE
1- Solar panel
2- Steel guide for anchoring
3- Wooden board 120x25 mm
4- Corrugated sheet, h 50 mm step 250 mm
5- Steel eyelet for anchoring
6- Swivel clamp
7- Right clamp
8- Tube
9- Omega steel profile
10- OSB panel 12,5 mm
11- Sheep wool insulation 100 mm
12- Vapour barrier
13- Wooden board 200x50 mm
14- Wooden board 200x25 mm
15- Steel bracket, steel tie-rod and bolt 10 mm
16- Aluminium gutter

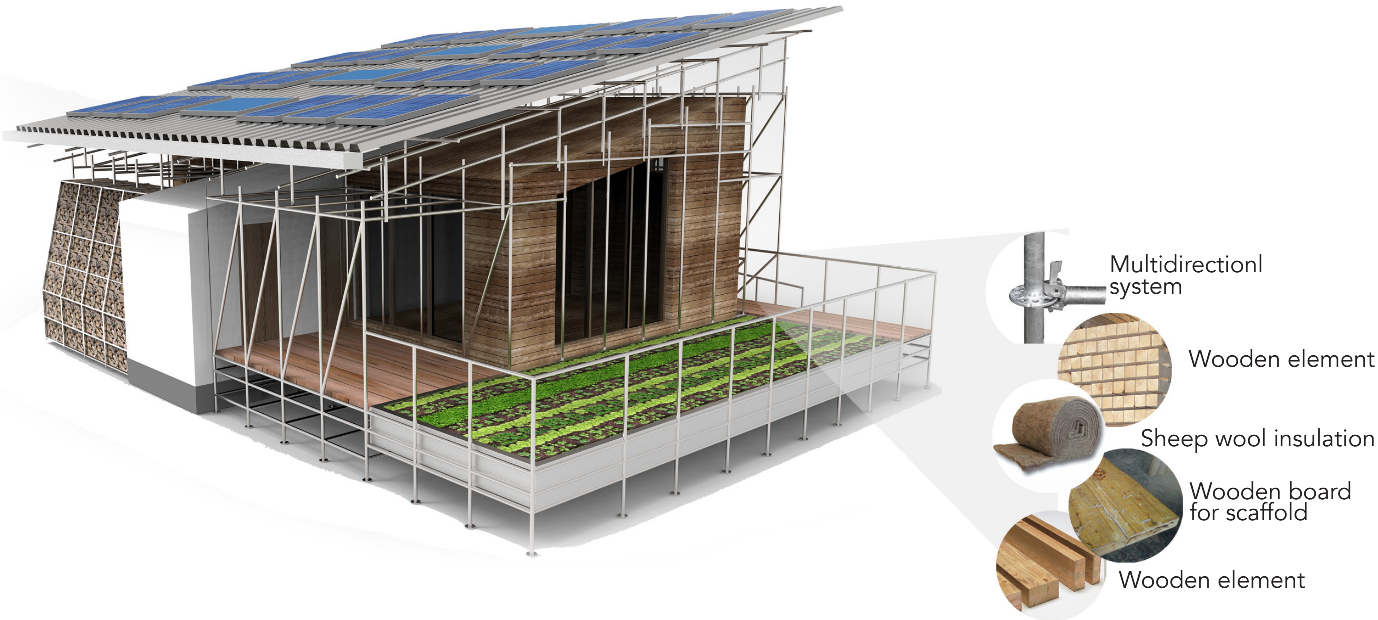
PROJECT SOLUTION 1



PROJECT SOLUITON 2



PROJECT SOLUTION 2

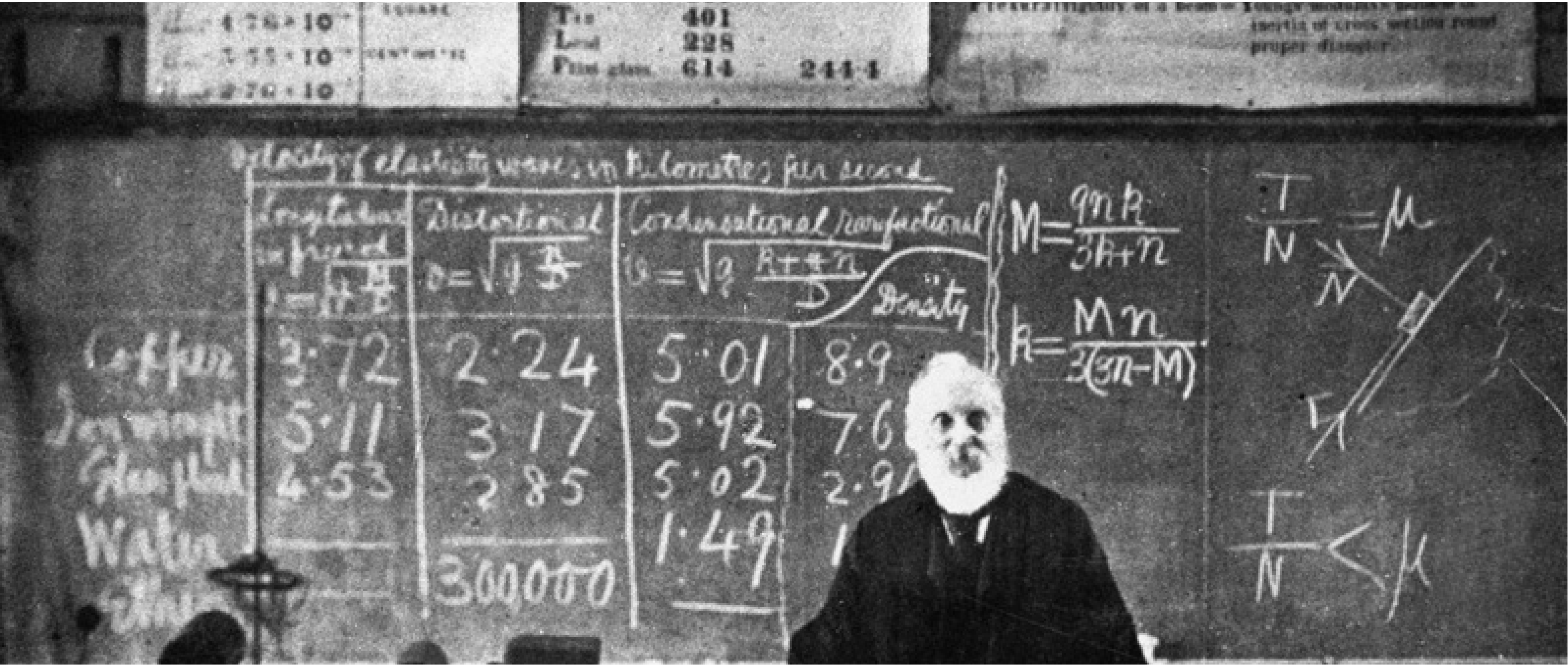


NOTES

1. *Galli F., Brunori G. "Short Food Supply Chains as drivers of sustainable development." Evidence Document. Laboratorio di studi rurali Sismondi, 2013, Isbn 978-88-90896-01-9*
2. *Born B., Purcell M. , "Avoiding the Local Trap: Scale and Food Systems in Planning Research", Journal of Planning Education and Research, 26, 2006195–207*
3. *Forlani M.C, Mastrolonardo L. "Sustainable building and local resources", Techne 7/2014, DOI:http://dx.doi.org/10.13128/Techne-14550 e*
4. *Forlani M.C. (a cura di) "L'università per il terremoto. Castelnuovo e l'altopiano di Navelli", Alinea editrice, Città di Castello, 2009*
5. *De Berardinis P., De Gregorio S.," Temporary systems after the earthquake in L'Aquila " WIT Press in volume 136 of WIT Transactions on the Built Environment- 2014*
6. *www.ipcc.ch*
7. *Calculation made with ECO-it 1.4 trial version*
8. *www.lcia-recipe.net*
9. *www.commissarioperlaricostruzione.it data 11th june 2015*
10. *www.comune.l'aquila.gov.it*
11. *As substitute by the article 149, paragraph 1, D.Lgs. 3rd August 2009, n.106.*
12. *As modified by Dlgs 179/2009 that has considered essential the remain in force of the DPR n. 320/56, limited to the articles from 1 to 41, from 44 to 70 and from 81 to 108.*
13. *As modified by: Royal Decree 2177/204, Royal Decree 604/2006, Royal Decree 1109/2007, Royal Decree 337/2010 and Low 32/2006.*
14. *In the legislation the special working clothes are defined as specific for the development of the working activity, meaning both the protection clothes and other kind of required clothes in specific sectors (pharmaceutical, food and electronic etc.).*
15. *The European standard EN 16194:2012 "Mobile non-sewer- connected toilet cabins- requirements of services and products relating to the deployment of cabins and sanitary products", identifies in 100 metres the maximum distance between the sanitary services and the construction site.*
16. *According to the "Linee guida per il rilievo, l'analisi ed il progetto di interventi di riparazione e rafforzamento/miglioramento di edifici in aggregato" of the reconstruction in Abruzzo for "structural aggregate can be considered a set of buildings (structural-building unit) not homogeneous, interconnected among them with a connection more or less structurally effective, determined by their evolutionary history that can interact under a seismic action or dynamic action. (...) In case of historical centres the aggregate where there are not present joints, as for example rue or other disconnections between the different building, coincides with the term (urban) of block, whose solution of continuity from the rest of the urban territory is made by the presence of streets and squares. The presence of elements as arches or contrast vaults, placed for linking contiguous aggregates, do not eliminate the possibility of delimitation and identification of the aggregates, where those elements are limited in number and extension and do not significantly alter the structural behaviour as a whole."*
17. *ROMVA 10, 2011, Il patrimonio ferito dell'Aquila, A.M. Reggiani, pp. 307-342.*
18. *The definition of the elements that constituted the safety systems happens through as described in the planimetric drawings, in the construction details and in the technical report, as filed in the "Ufficio messa in sicurezza centro storico" of the L'Aquila Municipality and integrated with the data obtained from surveys. In the calculation, it neglects the presence of wooden centrings, as even if generically described in the technical report, the drawings do not give enough information for a likely accounting. Also it neglects the presence of jacketing intervention in a wall parallel to Bominiaco street located at first floor within the building, as only limited information are available on the planimetric drawings that do not allow a reliable evaluation. For the used safety systems within the building it is neglected the deterioration considering the lack of exposure to atmospheric agents.*
19. *Det. Ordinat.165 of the 16/07/2009- L'Aquila. Last SAL paid with det. 353 of the 17/06/2010.*
20. *The analysis of deterioration is carried out with reference to the situation of safety systems on 7th April 2015.*
21. *Hegger M., Rosenkranz T., Fuchs M., Auch-Schwelk V. "Atlante dei materiali", UTET, Torino 2006*
22. *ISO 4628-3: 2003, Paints and varnishes -- Evaluation of degradation of coatings -- Designation of quantity and size of defects, and of intensity of uniform changes in appearance -- Part 3: Assessment of degree of rusting.*
23. *UNI EN ISO 12944-5: 2008, "Pitture e vernici - Protezione dalla corrosione di strutture di acciaio mediante verniciatura - Parte 5: Sistemi di verniciatura protettiva."*
24. *We consider a percentage linear increase (mm/year) of the corroded surface. Considering that in 6 years (2009-2015) a rusting degree of equal to R2-0.5% has been reached reached, the necessary time to the achievement of the rusting degree R3-1% is equal proportionally to 6 years.*
25. *Starting from the percentage corrosion data known for corrosivity class C3, they were proportionally deducted the data relative to the corrosivity class C2, using the values referring to the annual maximum mass loss for corrosion in the steel with a low carbon content expressed in the standard ISO 12944-2 "Paints and varnishes. Corrosion protection of steel structures by protective paint systems. Part 2: Classification of environments."*
26. *The analysis of the deterioration is carried out by comparison between the neighbouring buildings.*
27. *In the "Appendix E" supplied on digital media are listed the elements of the safety systems of the Civic Museum of Santa Maria dei Raccomandati, specifying*

the size and the deterioration.

28. *The durability is not a guarantee, but it is an indication that serves for programming the maintenance. The time of satisfaction of performance is ensured by the producer and generally has the lowest durability established by the standard ISO 12944-5:2007. "Paints and varnishes. Corrosion protection of steel structures by protective paint systems. Part 5: Protective paint systems."*
29. *The simulation is made to comparative aim. In case of finalized evaluation the bearing residual capacity of a profile UPN 180 that presents a mass loss of the 30% due to corrosion, will have to be carefully evaluated the localization of the phenomenon with the aim to identify the resistant residual actual section.*
30. *EN 1065:1998- Adjustable telescopic steel props-Product specifications, design and assessment by calculation and tests.*
31. *In the explicative circular n. 617 of the 2.2.2009 of the NTC 2008 in reference to wood wit irregular sections it is possible to read: "in absence of specific requirements, for what concerns the material classification, it can refer to as expected to the section rectangular elements, without considering the requirements for the wanes and the variations of transversal section, provided that the calculation shall take account of the real geometry of the cross sections."*
32. *UNI EN 13183-3:2005 "Umidità di un pezzo di legno segato - Parte 3: Stima tramite il metodo capacitativo."*
33. *UNI EN 13183-1:2003 "Umidità di un pezzo di legno segato - Determinazione tramite il metodo per pesata.*
34. *The European standard EN 351-1: 2006 "Durability of wood -based products- Preservative - treated solid wood-Part 1: Classification of preservative and penetration and retention," indicates the requirements of minimum penetration (in millimetres) that must be ensured in function of the penetration of the product and the analytics area (in millimetres) that must be analysed to verify the satisfaction of the requirements of retention (in g/sqm in case of surface treatment and in Kg/mc in case of impregnation). It is possible to identify a correspondence between the use classes and the penetration requirements that must be ensured, in function of the penetration class of the species. Please refer to paragraph 6.2.*
35. *The "Appendix F" is provided by digital media.*
36. *The comparison is carried out taking as reference the cubic meters of materials.*
37. *The assembly with 3 specialized workers in 8 working days is considered.*
38. *A distance equal to 200 km is considered, the calculation is made considering prices given by the Region Abruzzo. The cost is lower than the actual situation as it considers the weight of the material and not the volumetric encumbrance that increases the number of travels.*
39. *It is assumed that each aggregate corresponds to a different site.*
40. *As defined by the Norme Tecniche per le Costruzioni DM 14/01/2008 (Italy), paragraph 8.4.*
41. *As established by the Norme Tecniche per le Costruzioni DM 14/01/2008 (Italy), paragraph 2.4.1. "The nominal life of a structure VN is understood as the number of years in which the structure, provided that is subjected to an ordinary maintenance, must be able to be used for the purpose to which it is intended." For "Ordinary structure, bridges, infrastructures and dams with contained dimensions or of normal importance" VN>50 years.*
42. *Average weight of rubble for unit of empty for full volume= 573.16 kg/mc- Source: Stima quantificazione macerie, Direzione Regionale Abruzzo and CNR L'Aquila.*
43. *10 containers are needed for the demolition of half floor, they will be progressively transported in a temporary storage and emptied.*
44. *It is considered 0.64% as statistical data and it is increased by a share equal to 1% to take into account the existence of the elements for the safety.*



9_ MODALITY FOR THE CALCULATION OF CONVENIENCE TO REUSE

9.1 _ Reuse management

Reuse management can take place according to different scenarios, depending on the needs and interests of public administrations and companies.
The ownership of safety systems is of public administrations, as set out in the Circolare del Commissario Delegato per la Ricostruzione (Circular of the Deputy Commissioner for rebuilding) 4/28/2011 prot.1712/STM. Disassembly and storage transport are a burden to municipalities who entrust such tasks to the companies involved in the reconstruction of the building, subject to payment.
In addition, the public administrations should also support the burden of storage and disposal.
In view of the potential for reuse of materials/components resulting from the removal of safety systems, a company may have interest in acquiring them. The disposal represents a significant burden, which means that the interest and convenience for the company to acquire ownership of materials depends on the actual percentage for reuse. Even if the safety systems consist of materials/components that can not be immediatly reused by the company due to their features (e.g. steel profiles that have a low flexibility of reuse), residual performance and market value affect the convenience for the company purchasing them. For example, the used steel profiles can be sold at a price ranging between 0.70 €/kg and 1.0 €/kg, otherwise the iron has a price ranging between 0.06 €/kg and 0.10 €/kg.
Convenience is directly proportional to the percentage of elements with the potential for reuse and market value.
Therefore, there are two main scenarios for managing the reuse of such materials.
The first scenario is the purchase by the company of materials/components that make up the safety systems. The cost should be determined as a function of average age, degradation and properties of materials, and type of system (dimensions that affect the reuse, high risk of degradation in dismantling, etc.) in order to make the purchase profitable for the company.
Starting from the market price of the new material/component, it is applied to a coefficient that takes into account the age and a depreciation coefficient that takes into account the characteristics of the element. In this way, it is possible to determine the market value of material/component, which is the selling price of the same:

$Vm=Pn^* Cv^* Cd$

where:
Vm= market value
Pn= new price
Cv= coefficient of age
Cd= depreciation coefficient

The coefficient of age can be calculated as:

$Cv=1- ((As-Ap)/Vu_{1/4})$

where:
Cv= coefficient of age
As= year of dismantling
Ap= year of installation
$Vu_{1/4}$= number of years of useful life considering 1/4 of life that would have the element in standard living conditions.

The reduction in the number of years of useful life depends on boundary conditions in which the elements are placed in work and on the disassembly that they must undergo and assumes that in carrying out their function of safety, their performance has been lowered.

The depreciation coefficient is estimated by taking into account the following variables:

- difficulty of reuse due to geometric and dimensional characteristics;
- potential degradation in dismantling,
- lack of flexibility for reuse
- necessity of reconditioning and/or preventive treatments before reuse.

Assuming, for example, the calculation of the market value of a profile UPN200 that is 1.50 metres long (37.68 kg), which is derived from the dismantling of a safety system in 2015 that was installed in 2010, will obtain the following values.

The coefficient of age is equal to:

Cv= 1- ((2015-2010)/17,5))= 0,71

The depreciation coefficient, considering the short length and lack of flexibility for reuse, is Cd = 0.7

The price of this element is equal to:

Pn= €/Kg 3,62[1] * Kg 37,68= € 136,40

The market value is equal to:

Vm= € 136,40 * 0,71 * 0,7 = € 68,75

In this way, the company may purchase at a reasonable price materials with residual performance, while saving significantly on the cost. The company, once it becomes the owner, shall pay the cost of removal. For the portion of non-reusable materials, the company shall pay the cost of transport to recycling facilities or, where applicable, the cost of transportation and the cost of landfill. In case of permanent endogenous reuse, the company will have the economic advantage of not having to transport materials already present on site and the advantage of purchasing the materials at favourable prices, compared to the same components if purchased brand new.

For the portion of materials that will be used in temporary endogenous reuse, the company shall bear the costs of assembly, disassembly and transport to storage. However, these costs are offset by the cost that the company would also incur in the case of building site facilities with new components. Specifically, in the latter case, the company should support the costs of transport, at the beginning and end of the yard, while in the case of reusing the materials are already on site, which saves the transportation costs of site facilities.

For the portion of materials destined to exogenous reuse, the company will have to bear the cost of transport and storage, while awaiting future use. These materials represent an investment for the company, because with a sufficient performance, they may be reused in future building sites, which saves on the purchase of new materials.

Therefore, the advantage is derived from the competitively priced purchase of materials/components that make up the safety systems and from the possible use within the construction site and outside of it. The economic advantage that derives from the reduction of transport both of materials and of site facilities must be greater than the costs of dismantling the safety systems, transport to recycling or landfill of unusable portion and the transport and storage of reusable parts at the end-of-site.

On the basis of these considerations, it is evident that the economic advantage of the company to purchase materials depends to the percentage of reusable elements compared to the portion to give to landfill, to the type, characteristics and degradation of components and their immediate reusability within the site. There is a hierarchy of cost-effectiveness for reuse, with the same reconditioning treatment. We have, from the more convenient to the less convenient: permanent endogenous reuse, temporary endogenous reuse and exogenous reuse.

The municipality has the advantage of not having to provide disassembly, transport, storage and possibly disposing of these materials, with a positive impact from logistical and economic points of view.

The second scenario is when the public administrations maintain the property of safety systems, due to the lack of interest from companies to purchase the material. Therefore, the municipalities have the burden of providing the disassembly and subcontracting, in most cases, to the companies that deal with the reconstruction of the building. The companies shall also deliver materials in specific places indicated by public administrations.

Once placed in temporary storage, municipalities must provide for the sorting and identification of materials destined to the landfill and those with residual performances, which may be destined for recycling or reuse. The portion that does not have sufficient performance must be loaded, transported and delivered to the landfill. The remainder is loaded and transported to recycling centres or is stored. The conduct of these operations for public administrations represents a significant economic burden, as well as a logistical burden. In regards to the reusable part, the municipalities have access to materials that have zero cost (at present) for the construction of buildings intended for the community or to resell at competitive prices to the companies. In this case, however, the resale price must also include charges that supported the public administration for dismantling, transport, sorting and storage. Therefore, it must be higher than the market value (Vm) as previously calculated. A percentage varying between 20% and 50% should be added to this value. The price must not exceed the price given by the Pn*Cv, i.e. for the company it must always be convenient to purchase the materials, compared to the same new elements. It is clear that it is not possible for the municipality to recover the investment made in totality, but this mode restricts the expenditure supported, albeit minimally.

The choice by the public administration to resell the reusable materials or use them for building structures for collective use, depends on the availability of the material, on the needs of the community in terms of lack of services and on remaining investment opportunities.The construction of a building, although with a zero cost of materials, means an economic and logistic investment would be borne by the public sector.

In the second outlined scenario, the company obtains a gain from the dismantling and transport to storage of materials/components that constitute the safety systems.

It is evident for the public administration that the first scenario is cheaper in absolute terms, both logistically and economically. From an environmental point of view, although the ownership of the materials is obviously irrel-

evant, companies are able to guarantee, for their intrinsic modality of working, a greater chance of reuse for elements in comparison to the public administration, which has a greater propensity for recycling or landfilling. Therefore, the first scenario from an environmental point of view is most advantageous.
There is the possibility of intermediate scenarios resulting from the agreement between the parties on the basis of their respective interests.
With the convenience for the public administration to sell the materials before removal of the safety systems, it is possible to find ways to deal with the company in order to encourage buying.
One of the intermediate scenarios is the full or partial payment of dismantling to the company, provided that after this operation, the storage, sorting and transport will have to be completed by the same company.
The measure of payment for dismantling shall be as such to compensate the loss for the company resulting from the costs relating to the safety systems.
Another intermediate scenario is the resale to the company only the portion of reusable/recyclable materials that have market value. The municipality takes the burden of disposing the portion that has no residual performances. The company has the obligation of dismantling all safety systems and transporting only the reusable portion (which they bought). For the municipality, the burden of transportation and landfill is far less than the burden resulting from the dismantling, sorting, transport and storage of all materials that constitute the safety systems.
Another scenario is to financially reward companies that help decrease the environmental impact thanks to their choices. Public administration could take the burden of transportation to landfill for materials that do not have the minimum benefits for reuse and could donate the reusable materials to company, with the obligation to reuse them, which produces an environmental benefit. Economic facilitation granted to the company may be proportional to the reduction of environmental impact that derives from the reuse of elements
The described intermediate scenarios are not exhaustive, but help to find potential agreements between the companies and public administration.

9.2 _ Calculation tools

The described assessments are very expensive. For this reason, a format has been created, which evaluates the two primary scenarios, based on the results of which it is possible to define scenarios between the company and the public administration. We present an excel spreadsheet[2] (Appendix G) which aims to provide a quantitative indication in economic terms for the benefit of the government and the company, in terms of the environmental impact with repercussions to the community. With this tool, it is possibible to identify from an economic point of view the gain and expenses of the public administration and of the company in the two main scenarios described above, i.e. in the case where the company chooses to purchase safety systems, or if the company chooses not to buy them. Similarly, in both cases it will be possible to identify the environmental impact.
The data relating to the cost effectiveness are obtained starting from the quantity of materials/components that constitute the safety systems and consider the costs of disassembly, transportation and end-of-life scenarios, according to the pricelist of the "Preziario della Regione Abruzzo" (2013 or 2012 with ISTAT), update and asses the same price list for the costs of site facilities and new materials (mediated through specific coefficients as previously specified) that are saved when it proceeds to endogenous and exogenous reuse, according to the percentages specified in the file.
The environmental impact is calculated based on the values of the life cycle assessment provided by the literature[3] with respect to the parameters: PEI: non-renewable primary energy, GWP: global warming potential, AP: acidification potential, EF: eutrophication potential, POCP: summer smog and heating value. For each homogeneous fraction, the durability as a function of type of reuse (temporary and permanent endogenous reuse and exogenous reuse) has been assumed. The literature values were weighted with presumed durability for the specific type of reuse and the elapsed time from the moment of installation to disassembly. This will take into account that a lack of reuse involves a greater environmental pollution (due to all stages of life from extraction to landfill) into a smaller time frame. Otherwise, a permanent reuse that fully exploits the durability presumed in the production phase implies less environmental pollution because it is spread over a longer time span. Although these data are not related to the specific territory of L'Aquila; therefore, they cannot be considered valid in a specific sense. However, they provide a reliable comparison between the two hypotheses. Within the file, the data derived from the metric calculation, i.e. the specific amount for each element of the safety systems (as defined in the price list of "Prezzario della Regione Abruzzo") are as follows: the year of the implementation for the safety measures, the year of removal and the expected time for completion of the work on site. Subsequently, the reference scenario must be chosen and it should indicate the interest of the company to acquire ownership of the safety systems. In the case that the company is not interested in buying, it is postulated that the government should provide for the dismantling and transport by contract to an outside company. Then it is expected that the municipality has a chance for each material (wood, iron, steel and polyester) to choose the possibility between recycling, energy recovery, storage and landfilling. These choices must be specified using percentages for each fraction of the material present. The file automatically provides results in economic and environmental terms. Otherwise, if the company is interested in acquiring ownership of safety systems, for every material present in the metric calculation, it must be shown by percentage the portion intended for permanent endogenous reuse, temporary endogenous reuse and exogenous reuse. Consequently, it will be defined as the portion allocated to the end-of-life. Even in this case, each fraction of material must

be shown by percentage the choices related to end-of-life scenarios (recycling, energy recovery, storage and landfilling). For the portion of material that it is planned to be the temporary through endogenous reuse, it must indicate the savings in terms of site facilities that this reuse produces, specifically indicating the type of facilities that can be replaced by the building of the same through reused materials. In addition, each material must include the kilometres of transportation aimed at exogenous reuse and end-of-life scenarios, including an average value. Finally, to allow the calculation of the market value of the elements, if the technician deems it appropriate, it is possible to change the coefficient of age and the depreciation coefficient as calculated automatically in file by using a percentage coefficient.

After entering the above information, the file will automatically provide the results in economic and environmental terms.

Thanks to the knowledge from the results of the two main scenarios, it is possible to configure intermediate scenarios, which enable an agreement that is beneficial to both parties.

Take for example the calculation related to the safety system of Palazzo Brandani (via Bominiaco 12-14, L'Aquila)[4]. The data are placed in the corresponding spreadsheet[5]. The case of property maintenance by the government considers wood: recycling (50%) and energy recovery (50%), while steel is recycled at 100%. In this scenario, the public administration suffers a loss of about € 127000, while the company a gain (net of expenses) amounts to about € 16000.

In the case of purchase of the safety systems by the company, the following is expected for wood: temporary endogenous reuse 30%, exogenous reuse 50% and end-of-life 0%; for the pipe joints: temporary endogenous reuse 80% and exogenous reuse 20%; while for steel profiles it is assumed: temporary endogenous reuse 5%, permanent endogenous reuse 5%, exogenous reuse 60% and end-of-life 30%. These hypotheses have been made on the basis of the type of safety systems present and related assessments with the degradation of materials.

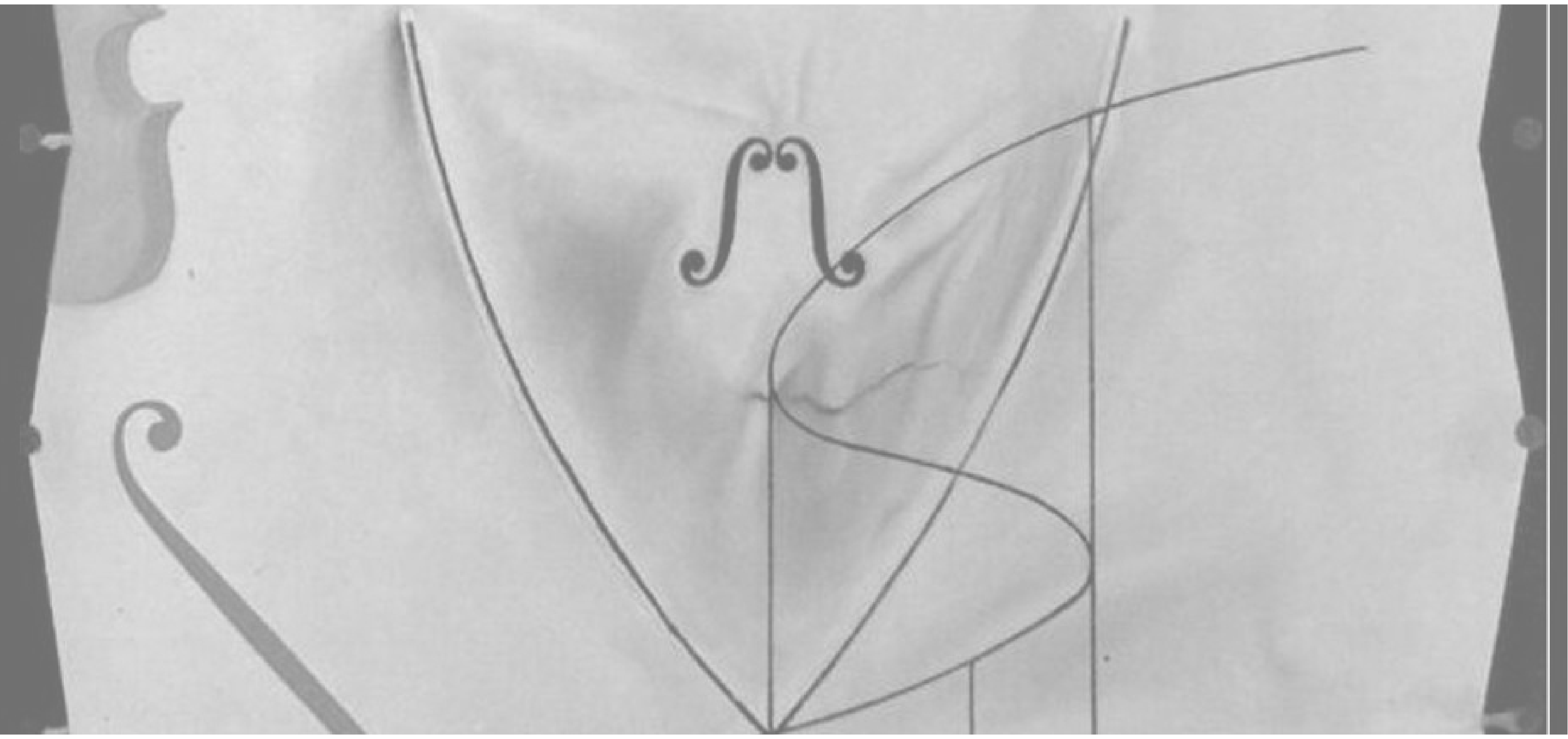
In this scenario, the municipality would have a gain of around € 20000 and the company a loss of about € 62000, mainly due to the dismantling fee. From an environmental point of view, the scenario where the company buys the safety systems has a lower impact (about 55%) than in the case where the safety systems remains the property of the government. Therefore, to encourage the company to buy safety systems, the municipality must compensate the loss of € 62000 that the company would have and add the net gain that it would have if it fails the purchase of approximately € 16000, for a total of € 78000. The intermediate scenario, therefore, may provide that the municipality transfers the property of the safety systems to the company at an amount equal to € 78000, in exchange, the company bears the burden of dismantling and the obligation of re-use in accordance with percentages previously established and the burden of transportation and landfilling of non-reusable parts[6]. For the municipality, this scenario represents a saving equal to € 49000 in relation to the case that it retains ownership of systems, as well as the relief of logistical burden and environmental benefit for the community.

The company makes a profit equal to what it would have if the public administration paid for the dismantling. It also has the advantage of buying affordable materials that have high residual performance and does not have the logistical burden of supply.

As previously explained, additional agreements between the municipality and the company can be assumed, which provide financial compensation according to the limitation of environmental damage. In view of the fact that if the portion reused is higher and the environmental damage is lower, such mechanisms would encourage companies to increase the proportion of reused materials.

NOTES

1. *The market value is obtained starting from the pricelist 02.10.50. In the "Prezzario della regione abruzzo 2013," net profits of the company, general expenses and labor.*
2. *The spreadsheet is provided on digital media. It is in Italian, as it will be used by public administrations and companies.*
3. *Hegger M., Auch-Schwelk V., Fuchs M., Rosenkranz T., "Atlante dei materiali"UTET, Milano, 2005*
4. *The metric calculation and technical designs were provided by "Ufficio messa in sicurezza centro storico del Comune di L'Aquila."*
5. *The spreadsheet example is provided in digital form.*
6. *The spreadsheet takes into account a company profit equal to 10% of the cost of production, as stipulated in the "Prezzario Regione Abruzzo". In fact, the income of company is often greater than this percentage; therefore, the financial compensation designed to encourage the purchase by the company of safety systems is really convenient for the enterprise.*



PHASE 6_ CONCLUSIONS.

An overview of the results divided into two categories is given: general conclusions regarding the building regeneration and specific conclusions relating to post-earthquake reconstruction in L'Aquila.
The general conclusions present the results obtained in the individuation of correlation between preliminary considerations for reuse. The preliminary considerations provided information about components/materials and parameters for the development of demolition operations, which are key to facilitating reuse that exploits all the residual performances of the elements. Good practice at international level stress the constructive, material and technological potential of elements often considered as waste, which are enhanced thanks to function changes. Enhancement of reuse passes through the definition of methodological-operative procedures relating to wood and steel that take into account the characteristics and potential of the analysed materials and put them in connection to environmental conditions and possible scenarios for intervention.
The specific conclusions present the results obtained through the practical application of these developed theories in the post-seismic reconstruction in L'Aquila. Data about safety systems were obtained and that allowed us to quantitatively define the importance of the problem and to identify the characteristics of the elements for the purposes of reuse. It was also defined a reuse process that allows the optimization and sustainability of the reconstruction process, which encourages promotion mechanisms for the local supply chain.
Through experimental projects of reuse (temporary endogenous, permanent endogenous and exogenous), it was possible to demonstrate the potential of waste materials derived from selective demolition of safety systems in L'Aquila in the definition of temporary buildings or in recovery operations and to define qualitatively and quantitatively the logistical, economic and environmental advantages. Beyond this, the conclusions present open problems and future research development.
The research introduces a methodological-operative process for the reuse of wood and steel, which can be defined for all commonly used materials in the construction field. In the development of the territory of L'Aquila, further research investigations have opened up to find more ways to encourage the reuse through reconstruction plans or economic incentives.

10_ CONCLUSIONS

10.1 _ General conclusions

The research has identified the implementation of bulding regeneration through the transformation of waste into resources for the territory. The local dimension as well as the waste reduction are guarantors of the sustainability of the regeneration process, which starts from the territory to reach the building.
The preliminary cognitive-analytical phase made it possible to carry out reflections at an international level concerning the potential of the wastes. Elements and parameters for the enhancement of end-of-life components and demolition operations have been identified.
Starting from a study of laws and European objectives related to waste reduction, the study of good practices in the field of construction made it possible to identify how to reuse the components. Concerning the materials used in architecture, there is a change of function when they have a lower performance compared to the first life cycle or use equal to the original one when performance is not varied. In regards to materials normally used in other fields that are reused in architecture, an adaptation to a new possible shape by careful design of the connections can be applied.
The methods, tools and techniques of demolition were analysed and we identified the selective mode to ensure the uniformity of the commodity fraction and the integrity of the elements. The attention and the programming of selective demolition phases is the *condicio sine qua non* for the reuse. For the purposes of subsequent studies and analysis it was crucial to establish the correlation between demolition and potential reuse of elements that derive from them. The analysis of examples allowed us to identify the possible ways of organising and managing demolition phases aimed at implementation of the environmental and economic advantages and to achieve a compromise between them.

The strong point of the research process is the dependency of the economic and environmental conveniences from operating at the regional level, which results in a progressive and urban regeneration development of a local sustainable supply chain based on closed cycles of matter. To encourage voluntary mechanisms of selective demolition, it is necessary to develop a market of local materials.
The processing phase of research identified methodological and operational process aimed at maximising the reuse of wood and steel. Regarding the wooden elements, the methodological-operative lines take into account degradation, potential treatments (preventive and curative), durability depending on the species, the climatic conditions in which they are placed and the minimum requirements for structural use. For the latter, the carried out lab tests showed the inadequacy of visual grading in the definition of the mechanical characteristics of the elements, when they are used. The visual grading, albeit always cautionary, does not provide results fully satisfying with the real property of the element, often resulting in an underestimation of the mechanical properties. The proposed process takes into account the information generated by the first lifecycle in order to exploit the real performance of the element and not those suppositories. This ensures the environmental sustainability of the reuse process.
Depending on specific characteristics of the element and suitable treatments, we defined the levels of reuse, by allowing the technician to evaluate with respect to boundary conditions and actual requirements at the time of reuse and the possible modalities of reuse, starting from a threshold of maximum exploitation of the potential of the element until it reaches a minimum threshold, which coincides with the landfilling.
As for the steel elements, we put in a system that meets the international standards and we singled out a methodological-operative process based on sequential logical steps, specific for reuse. Even in this case, reuse optimisation in-

volves analysis of information obtained from previous view cycles, analysis of the rate of steel corrosion and degradation, and of its protection treatment. The identification of possible treatments and accessible performances depend on the environmental corrosion class and a precise estimation of the durability, in order to program the maintenance. The identified procedures are specific for used elements, which maximises reuse, in order to take full advantage of their performance.
The specific knowledge of modalities of selective demolition, of the potential reuse of waste and the selection of a methodological- operative process for the reuse of wood and steel provide a valuable support for sustainable regeneration that trigger mechanisms of improvement for the whole territory.

10.2 _ Specific conclusions specific for the post earthquake reconstruction in L'Aquila

The research allowed us to define sustainable reconstruction modalities applicable in the territory of L'Aquila, which promote local resources and resolve logistical, economic and environmental issues related with this process. In particular, the research established methodological- operative lines aimed at transforming the problems related to the lack of programming for the end-of-life scenarios of materials resulting from the dismantling of the safety systems into an opportunity for innovation.
The specific cognitive analytical survey allowed us to characterise waste elements arising from the selective demolition of safety systems in L'Aquila.
Specifically, the analysis of economic data made it possible to establish the total amount invested by the government for the safety of buildings (approximately 212.3 million euros) and from it, thanks to the help of inspections, to identify the type of elements used. The identification of the type of safety measures according to the contrasted kinematic mechanism (tie-road, hooping, shoring, etc.) and the definition of dimensional, geometric and technological characteristics of components that constitute them have led to an abacus system that is useful to quickly locate properties of elements and design the reuse with respect to them.
Every applied constructive system was analysed in relation to reversibility, flexibility and ease of assembly/disassembly. These analyses allowed us to identify the correct methods of disassembly for each system and provided useful data to evaluate the reuse compatibility with a specific destination of use and function.
Subsequently, international examples using components similar to those used in the safety systems in L'Aquila and typological, dimensional, textured or geometric similarities with them were analysed from a technological point of view. Starting from 2010 (with rare exceptions), a trend of constructive experimentation that reuses elements typically found in the yard (formwork, telescopic props, tube-clamp system, multi-com system) was found. In some examples they are reused for temporary facilities with different function (restaurants, housing modules, exhibition buildings, etc.) with a temporary change of function. In other cases, they are used with stable function in the restoration of existing buildings in order to redefine the internal space.
Therefore, correlations were identified between the performance reached by the construction system and the priority requirements that a specific function requires, along with the correlation between the construction system and the formal possibility of building.
The cognitive-analytic phase highlighted the scale of the problem in terms of logistical, economic and environmental factors. This phase also provided specific information about safety systems and their constituent components that facilitate reuse and identify technological and compositional potentialities of the elements through experimental projects in an international context.
The experimental project phase made it possible to apply the theories found in L'Aquila. In particular a process for reuse was identified and applied, which enables optimisation in terms of money and time, sustainability of reconstruction and the creation of new economies based on a local production chain. Materials/components, as characterized above, were used for the definition of construction elements with high flexibility and reversibility that can be combined to create building systems, designed to define building organisms that support reconstruction.
The comparison between the building elements allowed us to identify the environmental compatibility of reuse, in regards to steel elements and the definition of the margins for compatibility between the construction system and the intended use.
The process for reuse made it possible to identify two major scenarios, i.e. endogenous and exogenous reuse.
The potential for temporary endogenous reuse was tested in the study of selective demolition of safety systems in the Civic Museum of Santa Maria dei Raccomandati (AQ) and in their immediate reuse for creating a common yard area that can be used by the building aggregate within a radius of 100 metres. The case study identified the benefits of this approach to recostruction from a logistical, environmental and economical point of view. The research introduced a new conception of the yard: switching from individualist visions of the yard to a collective dimension. At the same time, it reaffirmed the importance of the development of local resources, especially when they represent a waste, through the definition of temporary facilities, which by their nature require lower performance compared to stable buildings.
The regeneration of the territory and the buildings not only pass through the intervention applied on specific cases, but also through the construction site. To date, the construction yard has always been considered as a functional part for the implementation of the intervention, but it has always remained outside the logic of regeneration.
This approach also contributes to the sustainable development of the territory. The collective size of the yard and the attention to the resources of the territory are the two cornerstones for this innovative process. The organisation of common areas with programmed use for the companies facilitates and speeds up reconstruction, which simultane-

ously leads to a considerable decrease in environmental damage.
The reuse of materials/components derived from selective demolitions carried out in yards of ongoing reconstruction generates a cascade mechanism which leads to the sequential reconstruction of the city and, also, encourages the local chain. In addition, this operative mode has validity and can be applied in reconstruction after catastrophic events and urban regeneration interventions in portions of cities, i.e. whenever significant action is required on the building. In fact, the presence of common areas for companies and the coordinated programming of interventions, even if there are no issues related to road traffic, as in the case of L'Aquila, emerge as a profitable operation.
Similarly, even if the interventions are not implemented on a significant portion of the construction, but only on a single building, the presence of construction facilities drawing from the materials/components in the local supply chain produces virtuous cascading processes for the company and the community.
The verification of potential of permanent endogenous reuse was made by establishing schemes of possible operative modes of reuse for structural, technological and installation improvements in the building subject of reconstruction. The most frequent cases have been taken into account generalise the operational steps to ensure the replicability and variation of the described operation. The schemes can be used in the project to identify the reuse possibilities of elements, both in the operational phase to program the sequence of processing.
The verification potentiality for exogenous reuse was made through the application of theories developed in a case study regarding the demolition and reconstruction of buildings in L'Aquila, which were built after 1950. We identified the need in building regeneration to care not only for improving building performances, but also the users' needs during the period necessary for the construction intervention. We defined the phases of demolition and placed them in a system with the stages related to the building of temporary housing units to accommodate thepeople waiting for the completion of reconstruction. The housing modules are designed with materials resulting from selective demolition of safety systems from an adjacent building next to where the recovery intervention was made. It is possible to identify the relationships between the demolition schedule, the schedule for the building recovery and the schedule of temporary housing.
The study confirms that in order to ensure the regeneration of the territory, the concept of temporariness must become "local," meaning that the system is sustainable within a predetermined kilometre radius from the place of production, supply and disposal of materials/components.
Finally, the management of reuse (exogenous and endogenous) can be controlled via a spreadsheet that helps us to find scenarios that are logistically and economically convenient for both governments and companies involved in the reconstruction, without prejudice to the sustainability of the reconstruction process.

10.3 _ Further developments

With regard to the general processing phase of research, in reference to the wood, a field of research has opened in identifying a visual grading process that overcomes the paradox to exclude elements that have sufficient mechanical properties to such use and optimize the durability in reuse with environmental benefits. Experimental investigations can be performed on elements of different species of wood, in order to contemplate the conditionings arising from them. A further field of research is a correlation study between the properties of the element that can be reused and the visual grading, by investigating the mechanical properties that this research overlooked, in order to identify a process that optimises reuse.
Further developments of research open up under the definition of a methodological-operative process of reuse for building materials like concrete, brick, glass, etc., which have been overlooked because it is not present in the security systems in L'Aquila. In general, the research introduces important reflections about the need of specific legislation for elements that have already undergone one or more cycles of life, to stimulate the market for secondary raw materials.
In concern to the experimental project in L'Aquila, the research has highlighted the potential for waste elements resulting from selective demolitions. Further developments of research promotes ways to encourage reuse. For example, the definition of a reconstruction plan to organise the realisation of common yards that can be used by companies and that must be built with a compulsory part of reused local materials or even the definition of an economic incentive mode to produce voluntary mechanisms of reuse by companies.
Further research can also be conducted to study the relationship between existing local chains and potential local supply chains that can be developed via the enhancement of other reconstruction waste materials that this research overlooked, such as the rubble.

DIGITAL APPENDICES

Appendix A: microscopic analysis of n. 17 wooden elements subjected to experimental tests, for each element the cross, radial and tangential views are provided. (Chapter 6)

Appendix B: in reference to the wooden elements subject to experimental tests, we provide sheets for the description of the parameters used in the visual grading according to UNI 11035-2:2010 "Legno strutturale - Classificazione a vista dei legnami secondo la resistenza meccanica - Parte 2: Regole per la classificazione a vista secondo la resistenza meccanica e valori caratteristici per tipi di legname strutturale" and the UNE 56544:2011 "Clasificación visual de la madera aserrada para uso estructural. Madera de coníferas"; in the same sheets, the data and the photos of the flexion test are inserted. (Chapter 6)

Appendix C: in reference to wooden elements subjected to experimental tests, we provide sheets with the comparison between characteristic values identified through visual grading according to the Spanish legislation UNE 56544:2011 "Clasificación visual de la madera aserrada para uso estructural. Madera de coníferas," and characteristic values identified through visual grading according to Italian legislation UNI 11035-2:2010 "Legno strutturale - Classificazione a vista dei legnami secondo la resistenza meccanica - Parte 2: Regole per la classificazione a vista secondo la resistenza meccanica e valori caratteristici per tipi di legname strutturale," and real values (volumetric mass, modulus of elasticity and bending strength,) arising from laboratory tests. (Chapter 6)

Appendix D: the Life Cycle Assessment is calculated using the IPCC2007, 100 yr (kg CO2-eq) method with description of the impact of production, use and end-life for every designed constructive system. (Chapter 8, paragraph 3)

Appendix E: cataloguing of the elements that can be obtained in the disassembly of the safety systems of the Civic Museum of Santa Maria dei Raccomandati (AQ), for each element the size (conditioned by the type of disassembly) and the level of degradation are defined. (Chapter 8, paragraph 4)

Appendix F: cataloguing of the elements that are necessary to build the site services (offices, changing rooms, restroom and refectory) for their realisation in the common area, serving the aggregates within a radius of 100 metres. (Chapter 8, paragraph 4)

Appendix G: Excel spreadsheet for the calculation of convenience to reuse. (Chapter 9, paragraph 2)

BIBLIOGRAFY

Books and papers in books

ANPAR, BRESSI G. (eds.), Elementi chiave del settore del riciclaggio dei rifiuti da costruzione e demolizione

ANVVFC "VOLONTARIATO E PROTEZIONE CIVILE", Linee guida costruzione puntelli in legno, 2008

ANVVFC "VOLONTARIATO E PROTEZIONE CIVILE", Linee guida posizionamento di catene e tiranti, 2008

BAUMAN, Z., D'AMICO, S., Modus vivendi: inferno e utopia del mondo liquido. Laterza,Roma, 2007.

BELIZZI M., Le opere provvisionali nell'emergenza sismica, Agenzia di Protezione Civile. Servizio Sismico Nazionale, 2000.

BELLUZZI O., Scienza delle costruzioni, Zanichelli, Bologna 2001, vol. 1

BEVILACQUA P., La terra è finita, breve storia dell'ambiente, Editori laterza, Bari, 2006

BIANCHI R, MORABITO G., (eds.), Small Buildings. Dispositivi costruttivi leggeri per l'architettura. Rubbettino, Milano.

BODIG J., JAYNE B., Mechanics of wood and wood composites, Krieger Publishing Company, United States, 1993

BOLOGNA R., La reversibilità del costruire. L'Abitazione transitoria in una prospettiva sostenibile, Maggioli Editore, Repubblica di San Marino, 2002

BREEVORT G.H., ROEBUCK A.H., A Review and Update of the Paint and Coatings Cost and Selection Guide, Corrosion Performance, 1993

BUTERA F., Dalla caverna alla casa ecologica, Edizioni Ambiente, Milano, 2007

CAMPIOLI, A., Progettare oltre l'emergenza: spazi e tecniche per l'abitare temporaneo. Il sole, Milano, 2009, 24.

CAPUZ LLADRÓ, R.,BENLLOCH M.J.; HERMOSO P. E.; Métodos de ensayos no destructivos para la estimación de las propiedades físicas y mecánicas de las maderas; Universidad Politécnica de Valencia, 2003

CARSON R., Silent spring, Houghton Mifflin, Boston, 1962

Carta di Aalborg. Carte delle città europee. Per uno sviluppo durevole e sostenibile, 1994

CATERINA, G., Tecnologia del recupero edilizio. Unione Tipografico-Editrice Torinese, 1989.

CCIAA, La gestione dei rifiuti nell'attività di costruzione e demolizione, 2009

CHENUT D., Ipotesi per un habitat contemporaneo, Mondadori, Milano, 1968

CIB, Agenda 21 on sustainable construction, CIB Report Publication 237, 1999

COSTANZA R., Ecological Economics. Columbia University Press, 1991

DE BERARDINIS P., DE GREGORIO S., Temporary systems after the earthquake in L'Aquila " WIT Press in volume 136 of WIT Transactions on the Built Environment- 2014

DG ENV, Use of economic instruments and waste management performances, 2012

DI LAURO A., SICHER S., GRIMALDI D., ALBEZZANO G., VARAGLIOTI M., FABBRI A., SACCO C., CINQUETTI P., (eds.) Phare Twinning Project RO2004/IB/EN-07, Guidelines on ind. C&D Waste XX

DIPARTIMENTO DI PROTEZIONE CIVILE, ReLUIS, UFFICIO DEL VICE-COMMISSARIO DELEGATO PER LA MESSA IN SICUREZZA DEI BENI CULTURALI, STRUTTURA TECNICA DI MISSIONE, Linee guida per il rilievo, l'analisi ed il progetto di interventi di riparazione e rafforzamento/ miglioramento di edifici in aggregato.

DIREZIONE LAVORI PUBBLICI, CICLO IDRICO INTEGRATO E DIFESA DEL SUOLO E DELLA COSTA, PROTEZIONE CIVILE, SERVIZIO TECNICO REGIONALE DEI LL.PP., Prezzario Regione Abruzzo delle Opere Edili 2012

DIREZIONE LAVORI PUBBLICI, CICLO IDRICO INTEGRATO E DIFESA DEL SUOLO E DELLA COSTA, PROTEZIONE CIVILE, SERVIZIO TECNICO REGIONALE DEI LL.PP., Prezzario Regione Abruzzo delle Opere Edili 2013

DG ENV, Use of economic instruments and waste management performances, 2012

DOLCE M., Manuale delle opere provvisionali urgenti post-sisma, Convenzione tra Dipartimento Protezione Civile Ufficio Servizio Sismico Nazionale e l'Università degli Studi della Basilicata.

DONATO, F., GUAZZO, G. PLATANIA, M., Abitazioni per l'emergenza: ricerca per un sistema residenziale trasferibile, (a cura di Michele Platania), Veutro Editore, Roma, 1983

FOREST SERVICE US DEPT. OF AGRICULTURE, Woodhandbook, Forest Products Research, 1999

FORLANI M.C., (ed.), Cultura tecnologica e progetto sostenibile. Idee e proposte ecosostenibili per i territori del sisma aquilano, Alinea Editrice, Firenze, 2010

FORLANI M.C. (ed.), L'università per il terremoto. Castelnuovo e l'altopiano di Navelli, Alinea Editrice, Firenze, 2009

FORLANI M.C., DE GREGORIO S., Rigenerazione dell'ex ospedale Psichiatrico di Collemaggio (AQ) come nuovo habitat del futuro, Collana accademia dei Lincei (in press)

FORLANI M.C., DE GREGORIO S., The selective demolition: a "mine" for the sustainable buildings regeneration, 40th IAHS World Congress on Housing, Sustainable Housing Construction – IteCons- 2014

FORLANI M.C., DE GREGORIO S., Building reuse and urban revitalization, 3rd International Conference on Documentation, conservation and Restoration of the Architectural Heritage and Landscape protection. Proceedings. UPV Editor, 2015

FRAN BRETONES, J.M., Tecnología constructiva y sostenibilidad, in Cátedra del Hábitat Saludable n.1, 2009

FRIEDMAN Y., L'architettura di sopravvivenza, Bollati Boringhieri, 2003

DICOMAT VVF. , Capo del Dipartimento della Protezione civile, Terremoto Abruzzo: procedura per la messa in sicurezza di manufatti edilizi in emergenza sismica, n.860 del 06/05/2009

GALLI F., BRUNORI G. , Short Food Supply Chains as drivers of sustainable development., Evidence Document. Laboratorio di studi rurali Sismondi, 2013, Isbn 978-88-90896-01-9

GANGEMI V. (ed.), Riciclare in architettura. Scenari innovativi della cultura del progetto, Clean Edizioni, Napoli, 2004

GEORGESCU-ROEGEN N. , Bioeconomia, verso un'altra economia ecologicamente e socialmente sostenibile, (ed. Bonaiuti M.), Bollati Boringhieri, Torino, 2003

GIORDANO G., Tecnica delle costruzioni in legno, Hoepli, Milano, 1999

GIORDANO R., I prodotti per l'edilizia sostenibile . La compatibilità ambientale dei materiali nel processo edilizio, Sistemi Editoriali, Napoli, 2010

HEGGER M., ROSENKRANZ T., FUCHS M., AUCH-SCHWELK V. Atlante dei materiali, UTET, Torino, 2006

HOOKINS R., The Transition handbook, Green Books LTD, Totnes, Devon, 2009

LATOUCHE S., Le pari de la décroissance, Librairie Anthéme Fayard, 2006

LAVAGNA M., Life Cycle Assessment in edilizia. Progettare e costruire in una prospettiva di sostenibilità ambientale, Hoepli, Milano, 2008

LONGO D., Decostruzione e riuso. Procedure e tecniche di valorizzazione dei residui edilizi in Italia, Alinea Editrice, 2007, Firenze

MAGNAGHI A. , Progetto locale. Verso la coscienza di luogo, Bollati Boringhieri, Torino, 2010

MINISTERO DELL'INTERNO, CORPO NAZIONALE DEI VIGILI DEL FUOCO, Schede tecniche opere provvisionali.

NATTERER, HERZOG, VOLZ, Atlante del Legno, Utet, Torino, 1996

PALMERO L., DE BERARDINIS P., FORLANI M.C., DE GREGORIO S., Optimization of durability in the reuse of a steel element, 3rd International Conference on Documentation, conservation and Restoration of the Architectural Heritage and Landscape protection. Proceedings. UPV Editor, 2015

PERRICCIOLI; M., Abitare, costruire, tempo. Clup, 2004.

PERRICCIOLI M., La temporaneità oltre l'emergenza: strategie insediative per l'abitare temporaneo. Kappa, Roma, 2005

REGGIANI A. M. Il patrimonio ferito dell'Aquila, ROMVA 10, 2011, pp.307-342

REGIONE VALLE D'AOSTA, La gestione dei rifiuti inerti provenienti da interventi edilizi ed ambientali, 2011

SCHULITZ, SOBEK H., Atlante dell'Acciaio, UTET, Torino, 1999

SPADOLINI, P., GURRIERI, F., Pierluigi Spadolini: umanesimo e tecnologia. Electa, MIlano,1988.

VIGATO, F. L'architettura dell'effimero. Progettare gli eventi di spettacolo. libreriauniversitaria. it ed., 2010

VIOLA, S.; CATERINA, G. Il cantiere verticale per il recupero edilizio: sistema semiautomatico per la rimozione degli intonaci. 2009

Papers in journal

Abitare 508/2010, Heathcote E.A cena tra le impalcature. Ristorante Studio East Dining, Londra, Carmody Groarke.

Abitare 517, 2011, La complessità dei detriti. La lettura critica e poetica di Rotor sui prodotti e sui materiali della demolizione edilizia.

Architectural Record 10/2004, Knecht B., Designing for Disassembly and Deconstruction

A+t n. 39-40, Reclaim, Remediate, Reuse, Recycle

A+t n. 41, Reclaim Domestic Actions

A+t n. 42, Reclaim Domestic Actions 2

Costruire in laterizio 65/1998, Nironi L., Demolire per ricostruire: tecniche evolute di riciclaggio dei materiali, pp. 379-385

Costruire in laterizio 65/1998, Le Page J., Residenze Taviel a Saint-Omer. André Grobelny, Pierre Louis Carlier, , pp. 344-347

Detail 5/1994, Erweiterung einesWohngabaudes in Edinburg, Richard Murphy architects, pp.594-595

Detail 7-8/1998, Architectural Tent in Freiburg, GJL Architekten, PP 1434-1437

Detail 10/2002, The risks of demolitions and the opportunities offered by intelligend reduction. An interview with Uta Hassier.

Detail 11/2007, Centro di arti visive a Coimbra, Portogallo, pp. 1286

Detail 11/2009, Cente for Contemporary Culture, Arturo Franco, Fabrice van Teslaar Madrid, pp.1201-1206

Detail 10/2013, Thorsten H.,Hauke J., Matthias O., The retourn of Modula Construction, the adaptation of scaffolding to form the load bearing structures of buildings, pp.1128-1133

Esempi di architettura, vol.2, n.2, 2015 "Urban Renewal: from Demolition to Regeneration. Economic and Environmental Conveniences" Stefania De Gregorio, pp. 95-102

International Journal of Architectural Heritage, 9/2015 Cruz H. et al., Guidelines for the On-Site Assessment of Historic Timber Structures, pp.277–289

International Journal of Architectural Heritage: Conservation, Analysis, and Restoration 9/2015, Diodato M., Macchioni N., Brunetti M., Pizzo B., Nocetti M., Burato P., Sozzi L., Pecoraro E., Vegas López-Manzanares F., Mileto C., Understanding Spanish Timber Jack Arch Floors, Examples of Assessment and Conservation Issues, DOI: 10.1080/15583058.2015.1041193

Journal of Building Appraisal. 3(4)/2008, Piazza M., Riggio M., Visual strength-grading and NDT of timber in traditional structures, pp. 267-296

Journal of Natural Resources Policy Research, 2(4)/2010, Alexander, D. E. The L'Aquila earthquake of 6 April 2009 and Italian Government policy on disaster response. 325-342. Doi: 10.1080/19390459.2010.511450

Journal of Planning Education and Research, 26:195-207, 2006, Born B., Purcell M. , Avoiding the Local Trap: Scale and Food Systems in Planning Research, DOI: 10.1177/0739456X06291389

Modulo 211/1995, Nironi L. e Morfini L., Riduci, riutilizza, recupera, pp. 388-396

Modulo 237/1997, Ciotti C. e Dessy P., Macerie a rendere?, pp.11098-1104

Modulo 242/1998, Dessy P., Rifiuti e macerie a norma, pp. 536-540

Modulo 248/1998, Trentini G. e Zoppetti T., Demolire rispettando l'ambiente, pp.990-991

Officina, 4/1974, Marrone, E. Degradazione dei materiali: indagine conoscitiva per lo studio dei fenomeni di invecchiamento degli organismi architettonici.

SEI2012, Tecniche di demolizione

Prospettive Settanta, n.1/1980, Vittoria, E., La progettazione dell'incertezza.

Techne 5/2013, Forlani M. C., Environment and development in Reconstruction Plans in L'Aquila territory, pp. 74-81

Techne 7/2014, Forlani M.C, Mastrolonardo L., Sustainable building and local resources, , DOI:http://dx.doi.org/10.13128/Techne-14550

Tectonica n.18, Rehabilitación/estructuras, Intervenir en arquitecturas portantes, Ramos Galino F.J., Ramos Sanz A.

Tectonica n.19, Quintans Eiras C., Centro de las Artes Visuales en Coibra, Joao Mendes Ribeiro, pp. 48-61

Wood Science and Technology 23/1989, Sandoz, J.L., Grading of construction timeber by ultrasound, pp.95-108

European legislation

COM(2011) 571 Comunicazione della Commissione Tabella di marcia verso un'Europa efficiente nell'impiego delle risorse.

Directive 75/442/EEC of the Council of 15 July 1975 on waste.

Council Directive 76/403/EEC of 6 April 1976 on the disposal of polychorinated biphenyls and polychlorinated terphenyls.

Council Directive 78/319/EEC of 20 March 1978 on toxic and dangerous waste.

Directive 2006/12/EC of the European Parliament and of the Council of 5 April 2006 on waste.

Directive 2008/98/EC of the European Parliament adn of the Council of 9 november 2008.

EN 335: 1995, "Durability of wood and wood-based productos- Definition of hazard classes of biological attack."

EN 348:2004, "Structural timber – Determination of characteristic values of mechanical properties and density."

EN 351-1:2006 "Durability of wood and wood-based products- Preservative- treated solid wood- Part 1 : Classification of preservative and penetration and retention."

EN 408:2010. "Timber structures. Structural timber and glued laminated timber. Determination of some physical and mechanical properties."

EN 1065:1998 "Adjustable telescopic steel props - Product specifications, design and assessment by calculation and tests."

EN 14081-1:2005+ A1:2011 "Timber structures - Strength graded structural timber with rectangular cross section - Part 1: General requirements"

EN 13183-1:2002, "Moisture content of a piece of sawn timber. Determination by oven dry method".

EN 13438:2013 "Paints and varnishes - Powder organic coatings for hot dip galvanised or sherardised steel products for construction purposes."

EN 16194:2012 "Mobile non-sewer-connected toilet cabins - Requirements of services and products relating to the deployment of cabins and sanitary products"

EN ISO 8504-3: 1993; "Preparation of steel substrates before application of paints and related products -- Surface preparation methods -- Part 3: Hand- and power-tool cleaning."

ISO 1461:2009, "Hot dip galvanized coatings on fabricated iron and steel articles -- Specifications and test methods"

ISO 4628-2: 2003, "Paints and varnishes -- Evaluation of degradation of coatings -- Designation of quantity and size of defects, and of intensity of uniform changes in appearance -- Part 2: Assessment of degree of blistering"

ISO 4628-3: 2003, Paints and varnishes -- Evaluation of degradation of coatings -- Designation of quantity and size of defects, and of intensity of uniform changes in appearance -- Part 3: Assessment of degree of rusting

ISO 4628-4:2003, "Paints and varnishes -- Evaluation of degradation of coatings -- Designation of quantity and size of defects, and of intensity of uniform changes in appearance -- Part 4: Assessment of degree of cracking."

ISO 4628-5:2003, "Paints and varnishes -- Evaluation of degradation of coatings -- Designation of quantity and size of defects, and of intensity of uniform changes in appearance -- Part 5: Assessment of degree of flaking."-

ISO 8501-1: 2007, "Preparation of steel substrates before application of paints and related products -- Visual assessment of surface cleanliness -- Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings."

ISO 8501-2: 1994, "Preparation of steel substrates before application of paints and related products -- Visual assessment of surface cleanliness -- Part 2: Preparation grades for previously painted steel substrates, after localised removal of previous coatings."

ISO 8501-3:2006, "Preparation of steel substrates before application of paints and related products -- Visual assessment of surface cleanliness -- Part 3: Preparation grades of welds, edges and other areas with surface imperfections".

ISO 8502-6:2006, "Preparation of steel substrates before application of paints and related products -- Tests for the assessment of surface cleanliness -- Part 6: Extraction of soluble contaminants for analysis -- The Bresle method."

ISO 8502-12:2003, "Preparation of steel substrates before application of paints and related products -- Tests for the assessment of surface cleanliness -- Part 12: Field method for the titrimetric determination of water-soluble ferrous ions".

ISO 8503- 1-5, "Preparation of steel substrates before application of paints and related products -- Surface roughness characteristics of blast-cleaned steel substrates."

ISO 12944-2:1998, "Paints and varnishes -- Corrosion protection of steel structures by protective paint systems - Part 2: Classification of environments."

ISO 12944-3:1998, "Paints and varnishes -- Corrosion protection of steel structures by protective paint systems - Part 3: Design considerations."

ISO 12944-5:2007, "Paints and varnishes -- Corrosion protection of steel structures by protective paint systems -- Part 5: Protective paint systems"

ISO 14713:2009, "Zinc coatings -- Guidelines and recommendations for the protection against corrosion of iron and steel in structures".

ISO 14713-2:2009, "Zinc coatings -- Guidelines and recommendations for the protection against corrosion of iron and steel in structures -- Part 2: Hot dip galvanizing".

ISO 14919:2001, "Thermal spraying -- Wires, rods and cords for flame and arc spraying -- Classification -- Technical supply conditions."

Italian legislation

Lg. 366/1941 sulla raccolta, il trasporto e lo smaltimento dei rifiuti solidi urbani.

Lg 146/1994, "Disposizioni per l'adempimento di obblighi derivanti dall'appartenenza dell'Italia alle Comunità europee - legge comunitaria 1993."

Lg 308/2004 "Delega al Governo per il riordino, il coordinamento e l'integrazione della legislazione in materia ambientale e misure di diretta applicazione."

DPR n.320/56, "Norme per la prevenzione degli infortuni e l'igiene del lavoro in sotterraneo."

D.M. 14 gennaio 2008 "Approvazione delle nuove norme tecniche per le costruzioni."

Dlgs 22/1997 "Attuazione delle direttive 91/156/CEE sui rifiuti, 91/689/CEE sui rifiuti pericolosi e 94/62/CE sugli imballaggi e sui rifiuti di imballaggio."

Dlgs 52/1997 "Attuazione della direttiva 92/32/CEE concernente classificazione, imballaggio ed etichettatura delle sostanze pericolose."

Dlgs 389/1997 "Modifiche ed integrazioni al decreto legislativo 5 febbraio 1997, n. 22, in materia di rifiuti, di rifiuti pericolosi, di imballaggi e di rifiuti di imballaggio."

Dlgs 152/2006 "Norme in materia ambientale."

Dlgs 81/2008 "Attuazione dell'articolo 1 della legge 3 agosto 2007, n. 123, in materia di tutela della salute e della sicurezza nei luoghi di lavoro."

Dlgs 179/2009, "Disposizioni legislative statali anteriori al 1° gennaio 1970, di cui si ritiene indispensabile la permanenza in vigore, a norma dell'articolo 14 della legge 28 novembre 2005, n. 246."

Circolare esplicativa n.617 del 2.2.2009 delle NTC 2008

Dlgs 106/2009 "Disposizioni integrative e correttive del decreto legislativo 9 aprile 2008, n. 81, in materia di tutela della salute e della sicurezza nei luoghi di lavoro."

Dlgs 205/2010 "Disposizioni di attuazione della direttiva 2008/98/CE del Parlamento europeo e del Consiglio del 19 novembre 2008 relativa ai rifiuti e che abroga alcune direttive."

UNI EN 350-1:1996 "Durabilità del legno e dei prodotti a base di legno. Durabilità naturale del legno massiccio. Guida ai principi di prova e classificazione della durabilità naturale del legno."

UNI EN 350-2:1996 "Durabilità del legno e dei prodotti a base di legno. Durabilità naturale del legno massiccio. Guida alla durabilità naturale e trattabilità di specie legnose scelte di importazione in Europa."

UNI EN 408:2012 "Strutture di legno – Legno strutturale e legno lamellare incollato – Determinazione di alcune proprietà fisiche e meccaniche."

UNI EN 460:1996 Durabilità del legno e dei prodotti a base di legno. Durabilità naturale del legno massiccio. Guida ai requisiti di durabilità per legno da utilizzare nelle classi di rischio.

UNI EN ISO 9223: 2012, "Corrosione dei metalli e loro leghe - Corrosività di atmosfere - Classificazione, determinazione e valutazione."

UNI EN 10034: 1995 "Travi ad I e ad H di acciaio per impieghi strutturali. Tolleranze dimensionali e di forma."

UNI EN 10279:2002 "Profilati a U di acciaio laminati a caldo - Tolleranze sulla forma, sulle dimensioni e sulla massa"

UNI EN ISO 12944-1-8, "Pitture e vernici- Protezione dalla corrosione di strutture di acciaio mediante verniciatura."

UNI EN 13183-1:2003 "Umidità di un pezzo di legno segato - Determinazione tramite il metodo per pesata."

UNI EN 13183-3:2005 "Umidità di un pezzo di legno segato - Parte 3: Stima tramite il metodo capacitativo."

UNI EN ISO 14713:2010 "Rivestimenti di zinco - Linee guida e raccomandazioni per la protezione contro la corrosione di strutture di acciaio e di materiali ferrosi."

UNI CEN/TS 15003:2005 Durabilità del legno e dei prodotti a base di legno - Guida all'utilizzo di trattamenti termici per usi curativi contro gli organismi distruttori del legno.

UNI 11035-1:2010 "Legno strutturale - Classificazione a vista dei legnami secondo la resistenza meccanica - Parte 1: Terminologia e misurazione delle caratteristiche"

UNI 11035-2:2010 "Legno strutturale - Classificazione a vista dei legnami secondo la resistenza meccanica - Parte 2: Regole per la classificazione a vista secondo la resistenza meccanica e valori caratteristici per tipi di legname strutturale"

UNI 11035-3 "Legno strutturale - Classificazione a vista dei legnami secondo la resistenza meccanica - Parte 3: Travi Uso Fiume e Uso Trieste."

UNI 11119:2004 "Beni culturali. Manufatti lignei. Strutture portanti degli edifici. Ispezione in situ per la diagnosi degli elementi in opera."

Spanish legislation

Real Decreto 2177/2004 por el que se modifica el Real Decreto 1215/1997, de 18 de julio, por el que se establecen las disposiciones mínimas de seguridad y salud para la utilización por los trabajadores de los equipos de trabajo, en materia de trabajos temporales en altura. BOE nº 274 13/11/2004.

Real Decreto 604/2006 por el que se modifican el Real Decreto 39/1997, de 17 de enero, por el que se aprueba el Reglamento de los Servicios de Prevención, y el Real Decreto 1627/1997, de 24 de octubre, por el que se establecen las disposiciones mínimas de seguridad y salud en las obras de construcción. BOE nº 127 29/05/2006

Reale Decreto 1109/2007 por el que se desarrolla la Ley 32/2006, de 18 de octubre, reguladora de la subcontratación en el Sector de la Construcción.

Reale Decreto 337/2010 por el que se modifican el Real Decreto 39/1997, de 17 de enero, por el que se aprueba el Reglamento de los Servicios de Prevención; el Real Decreto 1109/2007, de 24 de agosto, por el que se desarrolla la Ley 32/2006, de 18 de octubre, reguladora de la subcontratación en el sector de la construcción y el Real Decreto 1627/1997, de 24 de octubre, por el que se establecen disposiciones mínimas de seguridad y salud en obras de construcción. BOE nº 71 23/03/2010

Legge 32/2006 reguladora de la subcontratación en el Sector de la Construcción. BOE núm. 250 de 19 de octubre BOE n. 250 19-9-2006.

UNE EN 460/1995 "Durabilidad de la madera y de los materiales derivados de la madera. Durabilidad natural de la madera maciza. Guía de especificaciones de durabilidad natural de la madera para su utilización según las clases de riesgo."

UNE EN 408/2011 +A1 "Estructuras de madera. Madera aserrada y madera laminada encolada para uso estructural. Determinación de algunas propiedades físicas y mecánicas".

UNE-EN 1912/2012 "Madera estructural, Clases resistentes, Asignación de calidades visuales y especies"

UNE 56544:2011 "Clasificación visual de la madera aserrada para uso estructural. Madera de coníferas"

SITOGRAPHY

corporate.arcelormittal.com

ec.europa.eu/environment/waste/pdf/2011_CDW_Report.pdf - Studio "Management of CDW in the EU"

isve.artemisinformatica.com

maps.google.it

ricostruzione.soalco.it

www.1024architecture.net

www.albertoalessi.com/ 1992

www.aberyo.com

www2.ademe.fr

www.archello.com/en/project/egg-333-remodeling

www.architectendvvt.com/projects/rot-ellen-berg/0/0/0/5

www.arturofranco.es

www.boxprefabbricati.eu

www.carmodygroarke.com

www.ceccantini.it

www.centrocisa.it

www.cominpont.it

www.commissarioperlaricostruzione.it

www.comune.l'aquila.gov.it

www.comune.laquila.it/pagina79_esiti-delle-verifiche-di-agibilita.html

www.condorteam.com

www.constructalia.com

www.cresme.it

www.detail-online.com

ww2.epa.gov

www.fracasso.it,

www.iuav.it/SISTEMA-DE/Laboratori5/cosa-offri/formazione/seminari--/ultimo-eve/protezione-legno.pdf

www.ipcc.ch

www.lcia-recipe.net

www.mataderomadrid.org/intermediæ.html

www.mercegaglia.com

www.nordzinc.com

www.pilosio.com

www.richardmurphyarchitects.com

www.silvestrirestauri.it

www.treccani.it/vocabolario/

www.ulmaconstruction.com

www.unipd.it

www.zincherie.com

www.zincoiblea.it

SPECIFIC DOCUMENTS

APAT 2006

Aggregati edilizi OPCM 3830/2010 s.m.i., Allegato Disp. Dir. Prot. 89969 del 13/10/2014

Det.Ordinat.165 del 16/07/2009 L'Aquila.

Elaborati tecnici depositati presso l'Ufficio messa in sicurezza centro storico del Comune di L'Aquila.

Ordinanza 3753/2009. "Eventi sismici provincia di L'Aquila, 6 aprile 2009. DICOMAC Funzione 1 – Tecnico Scientifica. Chiarimenti sugli esiti dei sopralluoghi effettuati su immobili oggetto di valutazione di agibilita' sismica."

OPCM n.3923 del 18.02.2011 "Ulteriori interventi urgenti a fronteggiare gli eventi sismici verificatisi nella Regione Abruzzo il giorno 6 aprile 2009. Norme in materia di smaltimento delle macerie."

OPCM n.4014 del 23.03.2012 "Ulteriori interventi urgenti a fronteggiare gli eventi sismici verificatisi nella Regione Abruzzo il giorno 6 aprile 2009."

SOFTWARE

ECO-it 1,4 trial version

TerMus-G. Acca software.

REFERENCES OF THE IMAGES

Phase 1

Cover- Sean Scully, Gabriel, detail, 1993, 259 x 366 cm. Collecció d'Art Contemporani, Fundació ''La Caixa'', Barcelona.

Chapter 1

Cover- Luis Palmero, L'Aquila, 2010

Phase 2

Cover- Schizzi del viaggio in oriente, Le Corbusier, 1911, fonte: www.tracce.it

Chapter 2

Cover- basurama.org

Fig.1- www.sfmoma.org

Fig.2- inhabitat.com

Fig.3- www.morethangree.es

Fig.4- raumlabor.net

Fig.5- www.pinterest.com

Fig.6- www.ruralstudio.org

Fig.7- inhabitat.com

Fig.8- www.dasparkhotel.net; www.viajesmonllar.com

Fig.9- www.palettenhaus.com

Fig.10- www.urbangallery.net

Fig 11- basurama.org

Fig 12- basurama.org

Fig.13- www.freitag.ch

Fig.14- www.flickr.com

Fig.15- www.archello.com

Fig.16- inhabitat.com

Fig.17- www.archdaily.com

Fig.18- it.wikipedia.org

Fig.19- www.recyhouse.be

Fig.20- proyectoblogspace.com

Fig.21-archrecord.construction.com/projects/bts/archives/civic/Westborough/photos.asp

Chapter 3

Cover- MERCADERRIBO, Avenida Aragón, 37 ctra. CV-300 La Pobla de Farnals

Fig.1- Centro Interuniversitario di Valutazione Qualità del Costruito del Politecnico di Torino

Fig.2- Elementi chiave del settore del riciclaggio dei rifiuti da costruzione e demolizione ANPAR

Fig.3- Copyright Stefania De Gregorio

Fig.4- ricostruzion.soalco.it

Fig.5- Copyright Stefania De Gregorio

Fig.6- Costruire in laterizio 65, "Residenze Taviel a Saint-Omer. André Grobelny, Pierre Louis Carlier", Jeanne Le Page, pp. 344-347

Fig.7- Costruire in laterizio 65, "Demolire per ricostruire: tecniche evolute di riciclaggio dei materiali", Laura Nironi, pag.380

Fig.8- Costruire in laterizio 65, "Residenze Taviel a Saint-Omer. André Grobelny, Pierre Louis Carlier", Jeanne Le Page, pp. 344-347

From fig.9 to fig.14- www.centrocisa.it

Fig.15- www.rotordb.org

From fig.16 to fig.18- Copyright Stefania De Gregorio

Fig.19 and fig.20 - Esempi di architettura, vol.2, n.2, 2015 "Urban Renewal: from Demolition to Regeneration. Economic and Environmental Conveniences" Stefania De Gregorio, pp. 95-102

From fig.21 to fig.23 -Copyright Stefania De Gregorio

From fig.24 to fig.26 - Esempi di architettura, vol.2, n.2, 2015 "Urban Renewal: from Demolition to Regeneration. Economic and Environmental Conveniences" Stefania De Gregorio, pp. 95-102

Phase 3

Cover- Rembrandt Harmenszoon van Rijn, Lezione di anatomia del dottor Tulp, detail, 1632, 169,5×216,5 cm. Mauritshuis, L'Aia.

Chapter 4

Cover- Copyright Stefania De Gregorio

Fig.1- MINISTERO DELL'INTERNO, CORPO NAZIONALE DEI VIGILI DEL FUOCO, Schede tecniche opere provvisionali

Fig.2- DOLCE M., Manuale delle opere provvisionali urgenti post-sisma, Convenzione tra Dipartimento Protezione Civile Ufficio Servizio Sismico Nazionale e l'Università degli Studi della Basilicata.

Fig.3- MINISTERO DELL'INTERNO, CORPO NAZIONALE DEI VIGILI DEL FUOCO, Schede tecniche opere provvisionali

Fig.4- Copyright Stefania De Gregorio

Fig.5 and fig.6- MINISTERO DELL'INTERNO, CORPO NAZIONALE DEI VIGILI DEL FUOCO, Schede tecniche opere provvisionali

Fig.7- Copyright Stefania De Gregorio

Fig.8 and fig.9- MINISTERO DELL'INTERNO, CORPO NAZIONALE DEI VIGILI DEL FUOCO, Schede tecniche opere provvisionali

Fig.10 and fig.11- Copyright Stefania De Gregorio

Fig 12 and fig.13 MINISTERO DELL'INTERNO, CORPO NAZIONALE DEI VIGILI DEL FUOCO, Schede tecniche opere provvisionali

Fig.14- Copyright Stefania De Gregorio

Fig.15 and fig.16- MINISTERO DELL'INTERNO, CORPO NAZIONALE DEI VIGILI DEL FUOCO, Schede tecniche opere provvisionali

Fig.17- Copyright Stefania De Gregorio

Fig.18- MINISTERO DELL'INTERNO, CORPO NAZIONALE DEI VIGILI DEL FUOCO, Schede tecniche opere provvisionali

Fig.19 and fig.20- Copyright Stefania De Gregorio

Fig.21- www.comipont.it

Fig.22- www.ulmaconstruction.com

Fig.23- www.comipont.it

Fig.24- Copyright Stefania De Gregorio

Fig.25- www.comipont.it

Fig.26- Copyright Stefania De Gregorio

Fig.27- MINISTERO DELL'INTERNO, CORPO NAZIONALE DEI VIGILI DEL FUOCO, Schede tecniche opere provvisionali

From fig.28 to fig.39- Copyright Stefania De Gregorio

Fig.40- MINISTERO DELL'INTERNO, CORPO NAZIONALE DEI VIGILI DEL FUOCO, Schede tecniche opere provvisionali

From fig.41 to fig.43-Copyright Stefania De Gregorio

Fig.44- MINISTERO DELL'INTERNO, CORPO NAZIONALE DEI VIGILI DEL FUOCO, Schede tecniche opere provvisionali

Chapter 5

Cover- www.dezeen.com

Exemplifying projects "Building restoration"- Detail 5/1994, Erweiterung einesWohngabaudes in Edinburg, Richard Murphy architects, pp.594-595; www.richardmurphyarchitects.com; Tectonica n.19, Quintans Eiras C., Centro de las Artes Visuales en Coibra, Joao Mendes Ribeiro, pp.48-61; Detail 11/2009, Cente for Contemporary Culture, Arturo Franco, Fabrice van Teslaar Madrid, pp.1201-1206; http://www.mataderomadrid.org/intermediæ.html; A+T: revista trimestral de Arquitectura y Tecnología, ISSN 1132-6409,N°.41,2013,págs.20-21;

https://www.archined.nl/2014/02/rot-ellen-berg-ontdubbeling-van-het-wonen/; A+T: revista trimestral de Arquitectura y Tecnología, ISSN 1132-6409, N°. 41, 2013, págs. 94-97 http://www.dezeen.com/2012/01/17/the-difference-of-ebitsuka-by-403architecture/; http://www.archello.com/en/project/egg-333-remodeling.

Exemplifying projects "Temporary structures"- Detail 7-8/1998, Architectural Tent in Freiburg, GJL Architekten, PP 1434-1437; www.gjl.de; www.detail-online.com; www.ateliergras.nl/projecten_details/5/eethuis.asp; www.landezine.com/index.php/2010/12/eathouse-by-marijke-bruinsma-marjan-van-capelle/; openhousebcn.wordpress.com/2011/11/25/openhouse-barcelona-eethuis-atelier-gras-holland-grow-your-own-house/; en.51artwork.com/atelier-gras-eathouse/;www.carmodygroarke.com/project/all/studio-east-dining.html; Abitare 508/2010, Heathcote E.A cena tra le impalcature. Ristorante Studio East Dining, Londra, Carmody Groarke.; www.1024architecture.net/en/2010/05/les-grandes-tables/; ristoranteinspirations.wordpress.com/2012/02/26/1024-architecture-temporary-restaurant-on-lile-seguin-paris/; www.dezeen.com/2011/10/20/les-grandes-tables-de-lile-by-1024-architecture/; www.dezeen.com/2012/02/20/the-wall-of-zudaji-by-403architecture/; A+T: revista trimestral de Arquitectura y Tecnología, ISSN 1132-6409, N°. 41, 2013, págs. 74-75; www.carlajuacaba.com.br/humanidade-pavilion/; www.archdaily.com/463532/humanidade-pavillion-2012-carla-juacaba-bia-lessa; www.designboom.com/architecture/carla-juacaba-pavilion-humanidade/

Phase 4

Cover- Raffaello Sanzio, Scuola di Atene, detail, 1509-1511, 500×770 cm, Musei Vaticani, Città del Vaticano

Chapter 6

Cover- Copyright Stefania De Gregorio

Fig.1- UNI EN 460:1996 "Durabilità del legno e dei prodotti a base di legno. Durabilità naturale del legno massiccio. Guida ai requisiti di durabilità per legno da utilizzare nelle classi di rischio"

Fig.2- UNI EN 350-2:1996 "Durabilità del legno e dei prodotti a base di legno. Durabilità naturale del legno massiccio. Guida alla durabilità naturale e trattabilità di specie legnose scelte di importazione in Europa."

Fig.3- provided by Maria Diodato

From fig.4 to fig.20- Copyright Stefania De Gregorio

Chapter 7

Cover- Copyright Stefania De Gregorio

Fig.1- BREEVORT G.H., ROEBUCK A.H., A Review and Update of the Paint and Coatings Cost and Selection Guide, Corrosion Performance, 1993

Fig.2-http://www.pokrasim-vse.ru/zashhita-ot-korrozii/texnologiya-zashhity-ot-korozii/

Fig.3- ISO 8502-3:1992, "Preparation of steel substrates before application of paints and related products -- Tests for the assessment of surface cleanliness -- Part 3: Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method)."

Fig.4- ISO 8502-6:2006, "Preparation of steel substrates before application of paints and related products -- Tests for the assessment of surface cleanliness -- Part 6: Extraction of soluble contaminants for analysis -- The Bresle method."

Fig.5- www.nordzinc.com

Fig.6- ISO 14713-2:2009, "Zinc coatings -- Guidelines and recommendations for the protection against corrosion of iron and steel in structures -- Part 2: Hot dip galvanizing."

Fig.7- UNI EN 10279:2002 "Profilati a U di acciaio laminati a caldo - Tolleranze sulla forma, sulle dimensioni e sulla massa" e UNI EN 10034: 1995 "Travi ad I e ad H di acciaio per impieghi strutturali. Tolleranze dimensionali e di forma."

Phase 5

Cover- Schizzi di Leonardo Da Vinci, www.windoweb.it/guida/arte/arte_foto/leonardo_da_vinci_08.jpg

Chapter 8

Cover- Copyright Stefania De Gregorio

Fig.1- www.lcia-recipe.net

Fig.2- www.commissarioperlaricostruzione.it

From fig.3 to fig.25- Copyright Stefania De Gregorio

Chapter 9

Cover- Photo Lord Kelvin in front of the blackboard, 1899, www.indire.it/immagini/immag/ultyoly/pi171.jpg

Phase 6

Cover- Salvador Dalí, La coda di rondine, detail, 1938, 73×92,2 cm, Museo Dalì, Figueres

Chapter 10

Cover- www.6aprile.it

RINGRAZIAMENTI

Ringrazio l'Università degli Studi "G. D'Annunzio" Chieti-Pescara e l'Universitat Politècnica de València e le relative scuole di dottorato in cui ho svolto questo percorso di crescita. Ringrazio il "Electron Microscopy Service" e il "Materials Laboratory" della UPV per il loro supporto logistico.

Ringrazio la Prof.ssa Forlani, il Prof. Palmero e il Prof. De Berardinis per avermi guidato con pazienza e dedizione, supportandomi nelle difficoltà incontrate e plasmando la mia forma mentis. In modo particolare, ringrazio la Prof.ssa Forlani per la sua onestà intellettuale che mi ha offerto la possibilità di iniziare il mio percorso accademico e per aver creduto in me dall'inizio, ringrazio il Prof. De Berardinis per aver continuamente stimolato in me la curiosità per la ricerca e il Prof. Palmero per avermi accolto a Valencia e per il suo ruolo determinante nell'internazionalizzazione della tesi.
Ringrazio tutti i professori e i colleghi che tramite consigli o critiche costruttive mi hanno permesso di migliorare il mio progetto di ricerca, tra cui: Prof. García Ballester, Prof. Fernandez Plazaola, PhD Ing. Antonello Cucchiella, PhD Arch. Maria Diodato, A. tec. Jorge Martinez, Arch. Serena Motta.

Ringrazio la Fondazione Ferdinando Filauro, nella persona del presidente Prof. Enzo Chiricozzi per aver finanziato la mia ricerca, dandomi l'opportunità di accrescere la mia formazione presso l'Universitat Politècnica de València, ma soprattutto perché il finanziamento ricevuto mi ha consentito di dedicarmi esclusivamente alla ricerca e di credere nel ruolo che essa ha nel produrre un miglioramento nella società, contrariamente al messaggio che i dottorati "senza borsa" trasmettono ai giovani ricercatori come me.

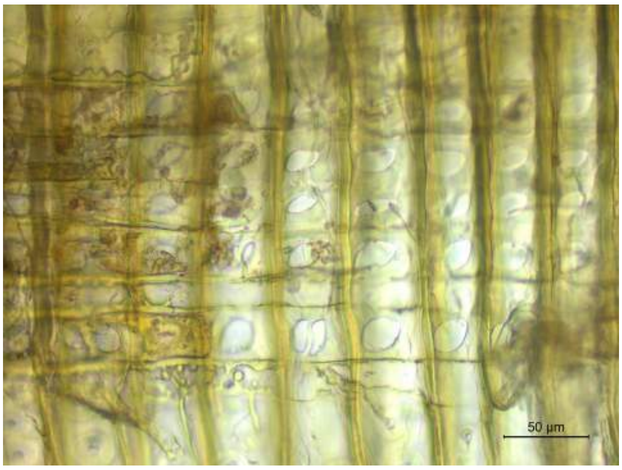
Ringrazio i miei genitori perché sono un punto di riferimento, per avermi insegnato a credere in me stessa, a continuare il percorso anche quando è difficile, perchè in quanto dono vale sempre la pena di essere vissuto. Ringrazio Fabrizio per il modo silenzioso in cui mi rassicura e per i continui stimoli dei nostri duelli intellettuali. Ringrazio Ivan per aver condiviso con me ogni giorno di questa avventura e per avermi lasciato la libertà di fare scelte importanti, incoraggiandomi incondizionatamente. Ringrazio la nonna Bianca, gli zii Luciano, Franca, Tonino, Anna Rita e Lino e i cugini Paolo, Carlo, Eugenia, Gianmarco e Piergiorgio perché sono un supporto fondamentale per la mia vita.

Ringrazio Benedetta perché affrontare insieme questo percorso lo ha reso possibile, per le preoccupazioni, le speranze e i progetti che abbiamo condiviso e che condivideremo. Ringrazio Irene e Fabio per la loro amicizia, perché riescono ad essere presenti con positività nella mia vita indipendentemente da dove mi trovi e da come mi senta. Ringrazio Renata perché il suo sguardo ottimista e ironico è contagioso e alleggerisce la mia visione "semi-seria" del mondo. Ringrazio Sara perché il suo comprendere le preoccupazioni e aspirazioni di questo percorso non mi ha fatto sentire sola, Tullio per le nostre sporadiche ma intense chiacchierate sul senso della vita e Riccardo per la sia simpatia. Ringrazio Ettore, Raffaella, Katia, Enrico, Loris e Barbara, l'equipe di predicazione e Don Valentino, perché la vita di ognuno di loro è testimonianza dell'Amore di Dio. Ringrazio Luna per il suo aiuto, perché la sua accoglienza è per me una certezza. Ringrazio Ida per la sua disponibilità gratuita nello studio dell'inglese. Ringrazio gli amici del Coretto in particolare Alessandra e Federica, la cellula San Michele e gli amici dell'IRP dell'Universitat Politècnica de València perché mi hanno fatto e mi fanno sentire a casa.

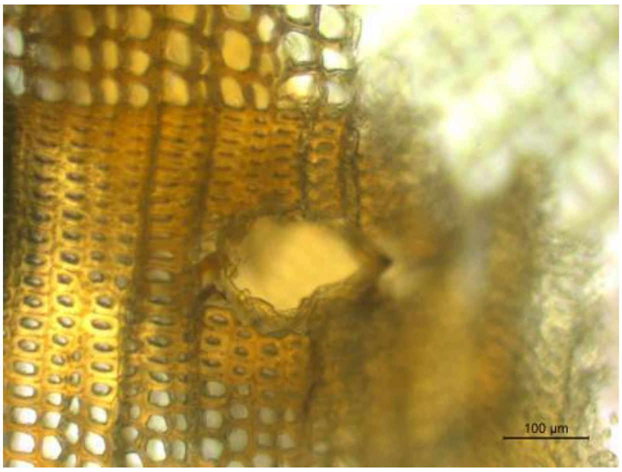
Ringrazio Dio per tutto questo, perché è solo grazie a tutte le persone che mi hanno accompagnato che sono arrivata alla fine di questo bellissimo percorso.

APPENDIX_ A

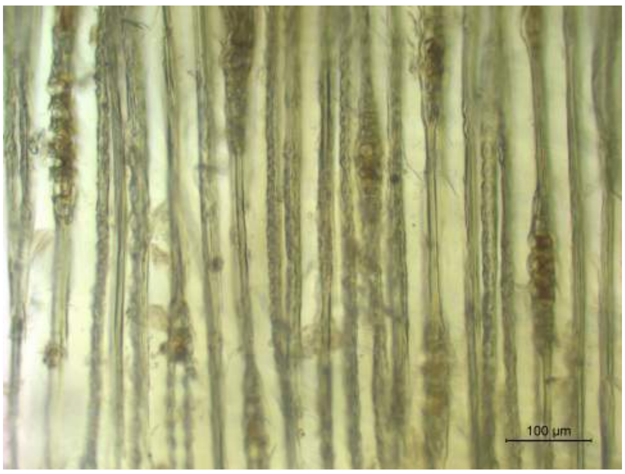
ELEMENT N.1



Radial view

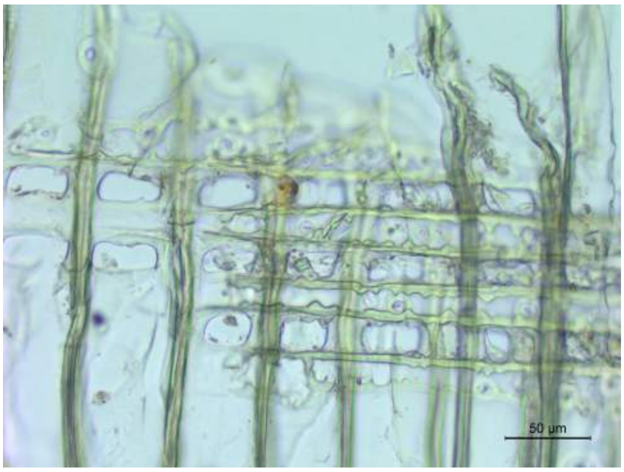


Transversal view

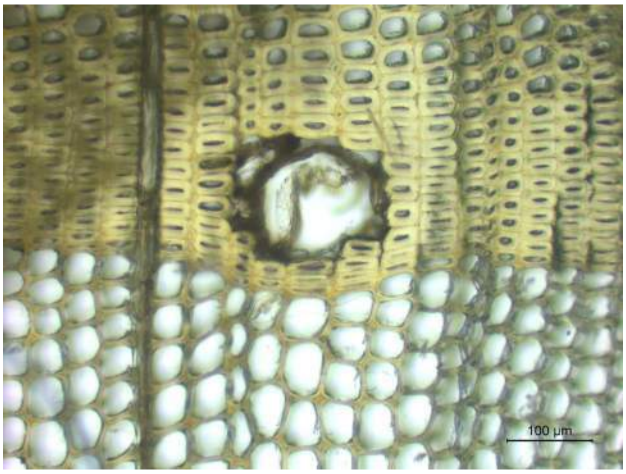


Tangential view

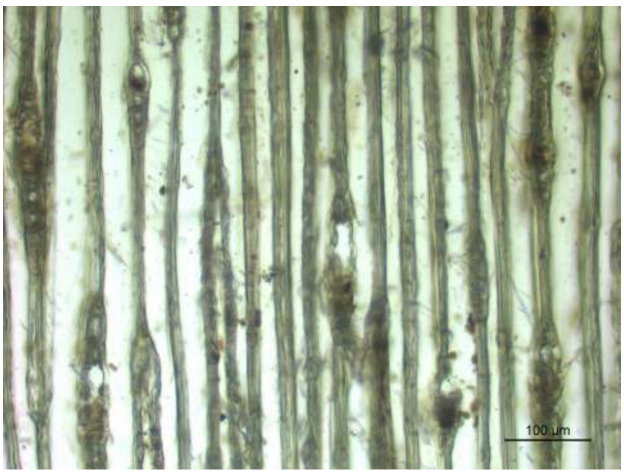
ELEMENT N.2



Radial view

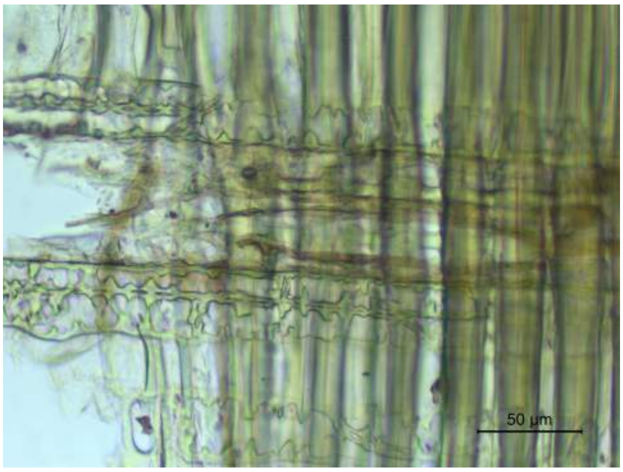


Transversal view

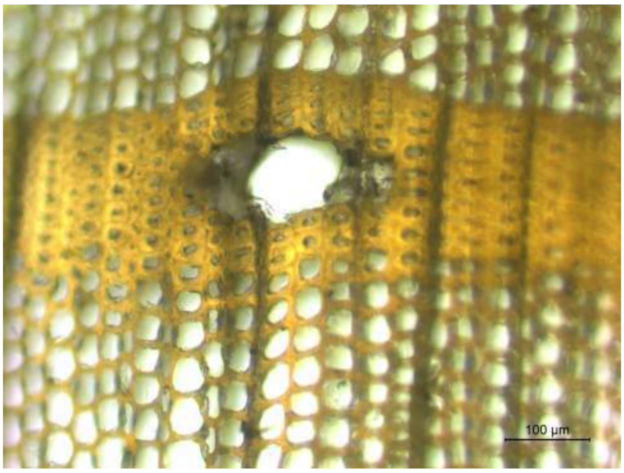


Tangential view

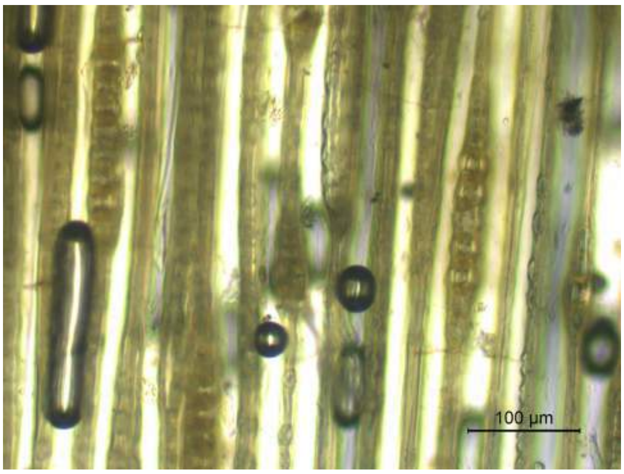
ELEMENT N.3



Radial view

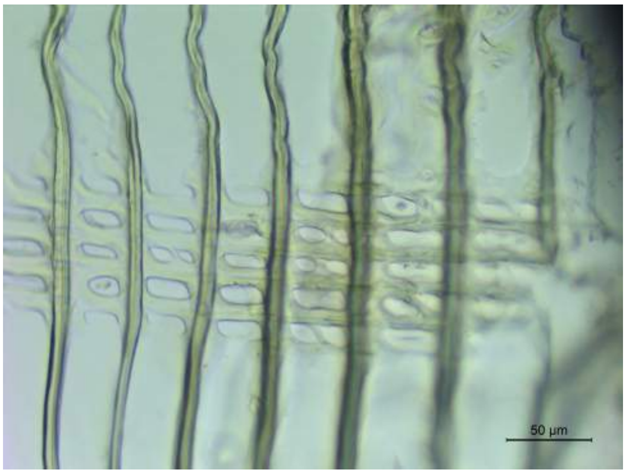


Transversal view

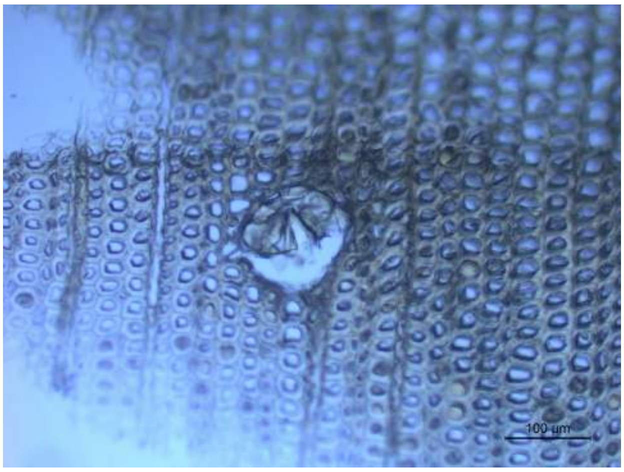


Tangential view

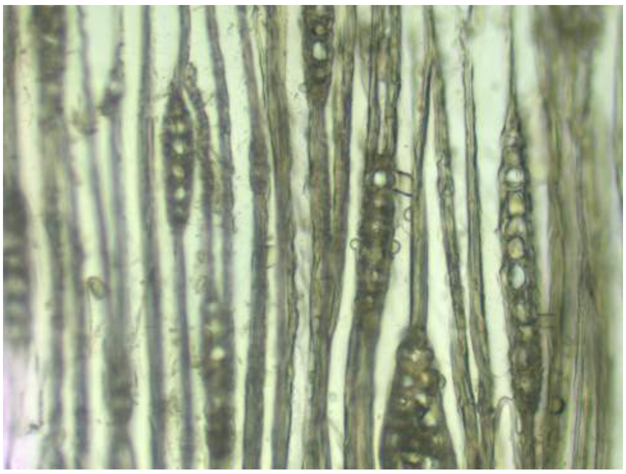
ELEMENT N.4



Radial view

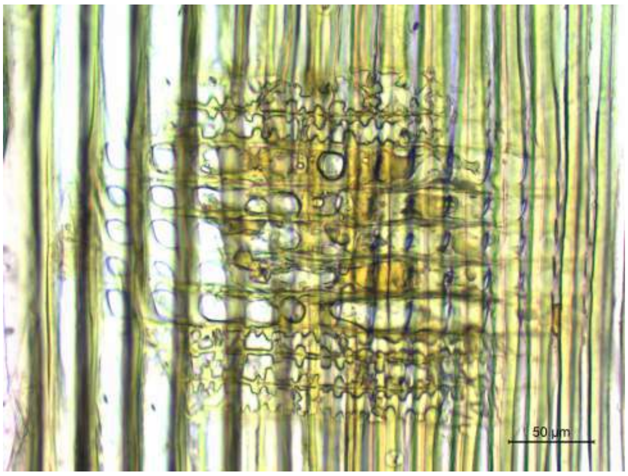


Transversal view

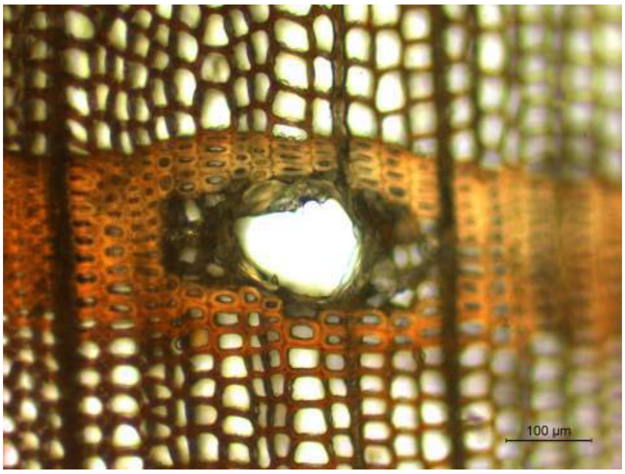


Tangential view

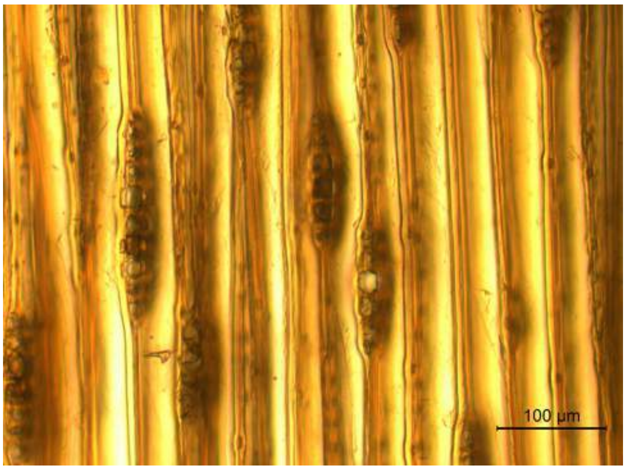
ELEMENT N.5



Radial view

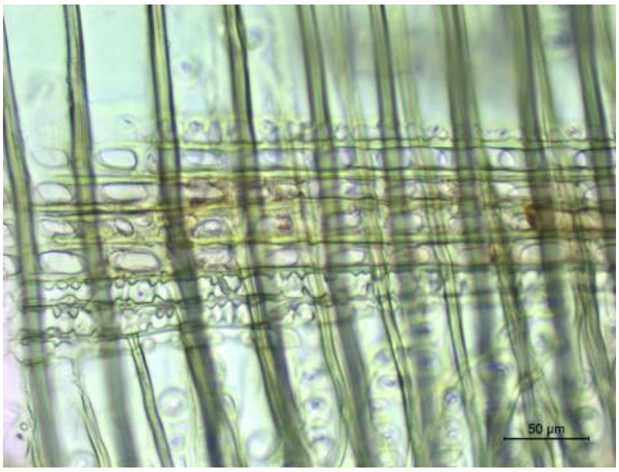


Transversal view

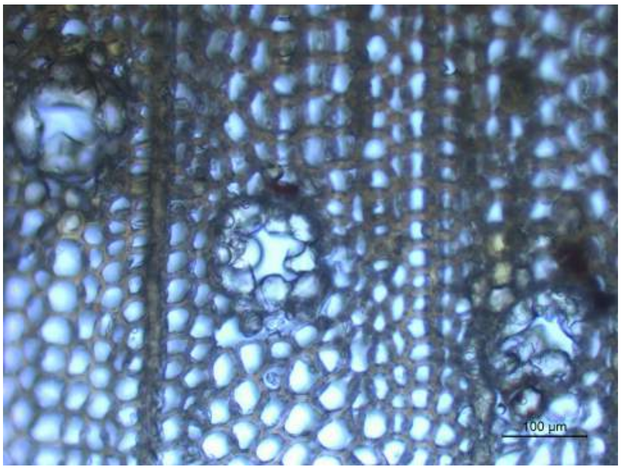


Tangential view

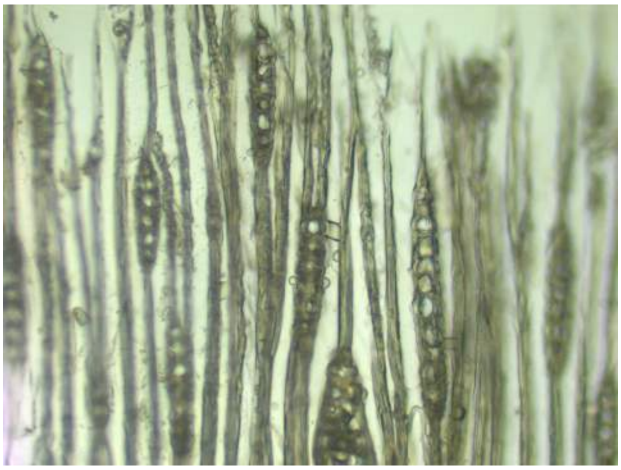
ELEMENT N.7



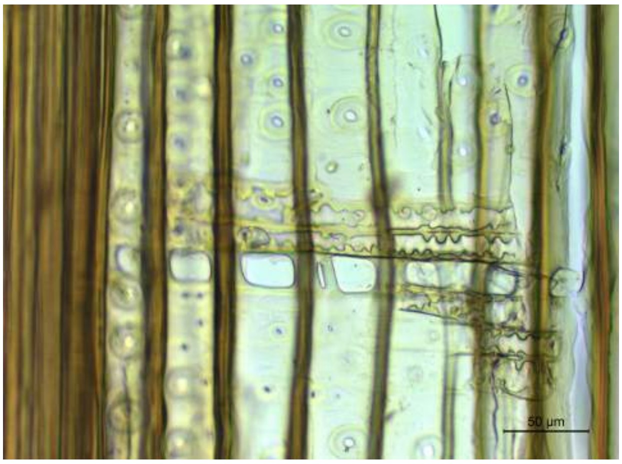
Radial view



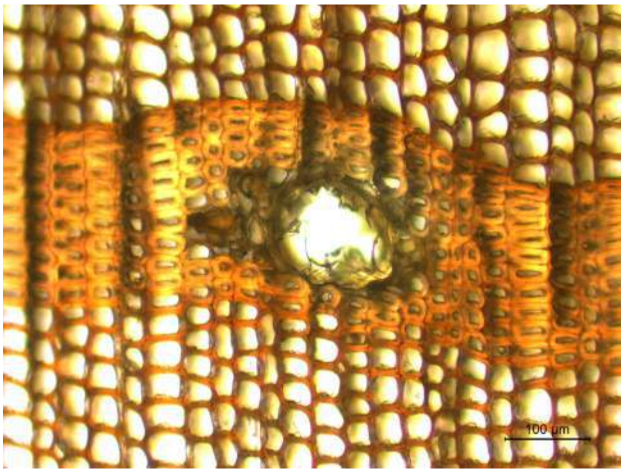
Transversal view


Tangential view

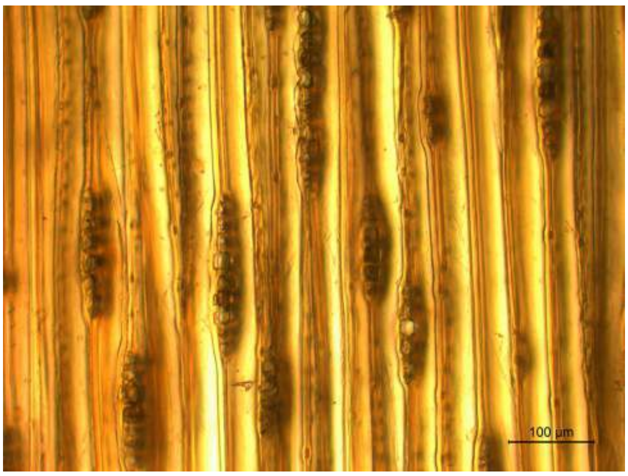
ELEMENT N.8



Radial view

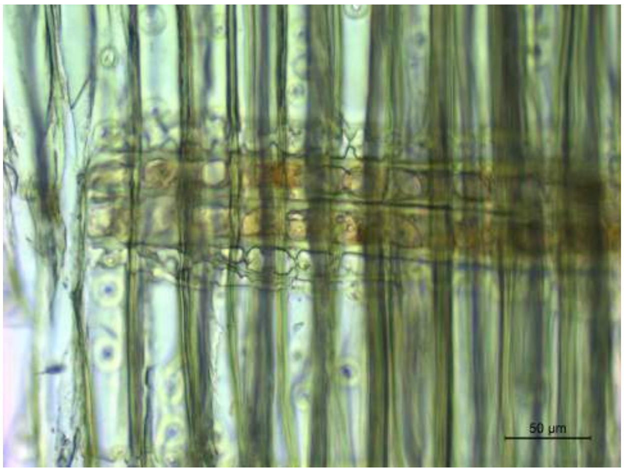


Transversal view

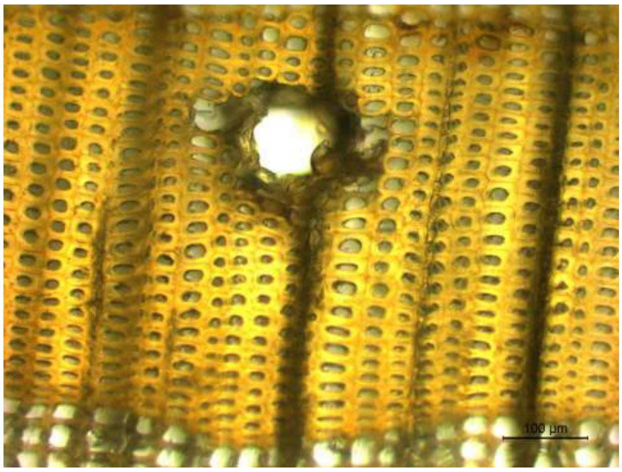


Tangential view

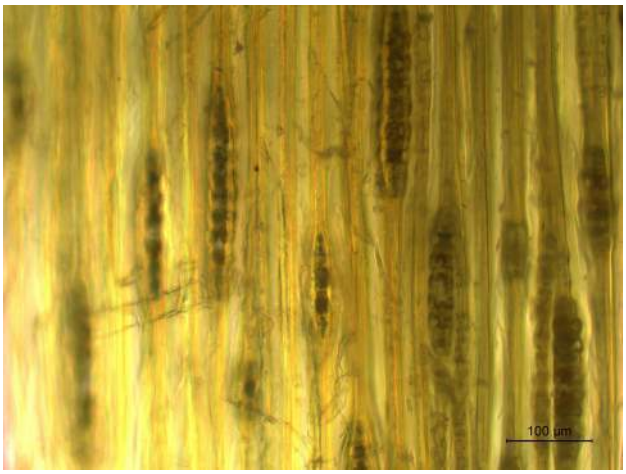
ELEMENT N.10



Radial view

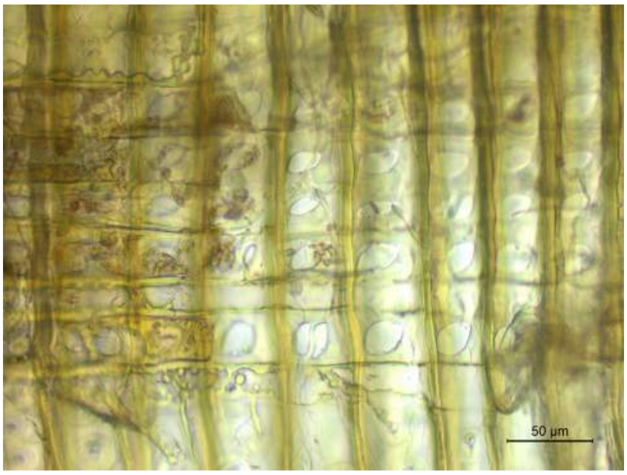


Transversal view

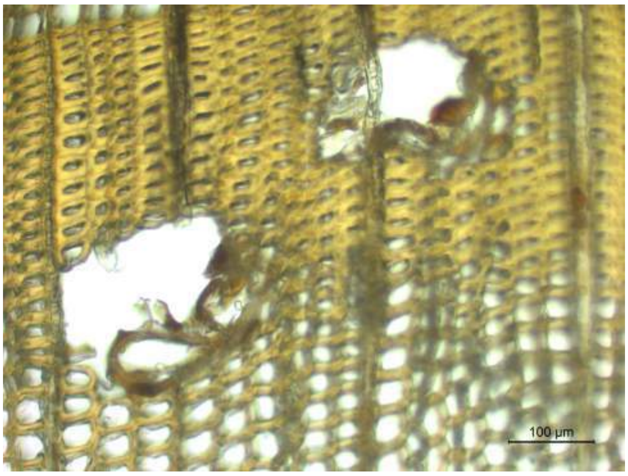


Tangential view

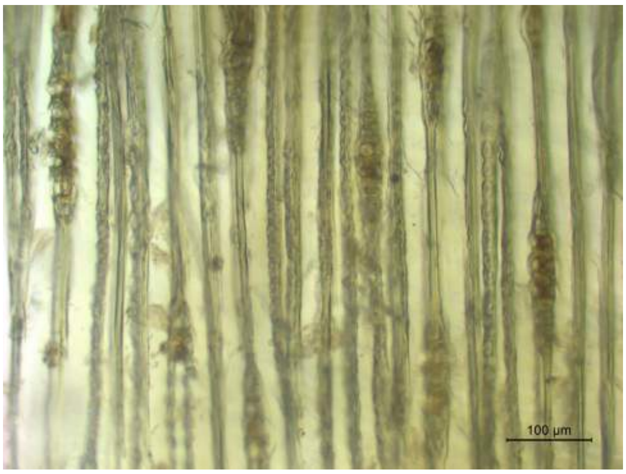
ELEMENT N.11



Radial view

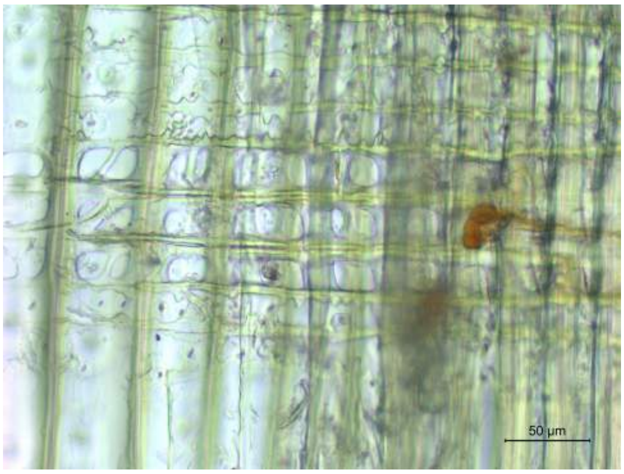


Transversal view

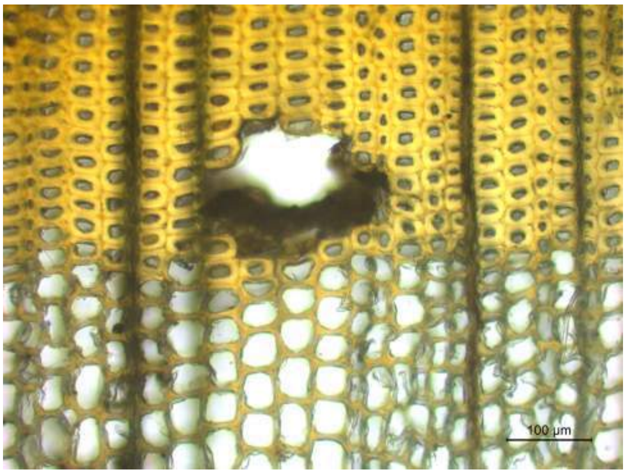


Tangential view

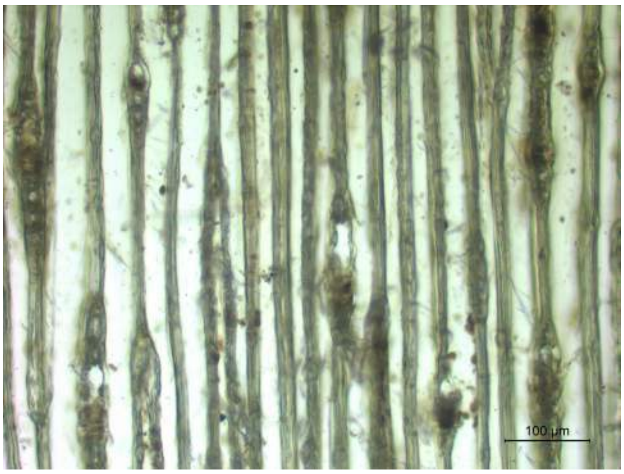
ELEMENT N.12



Radial view

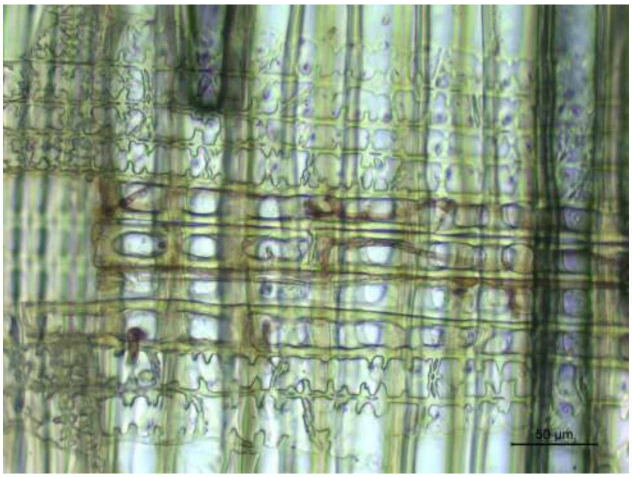


Transversal view

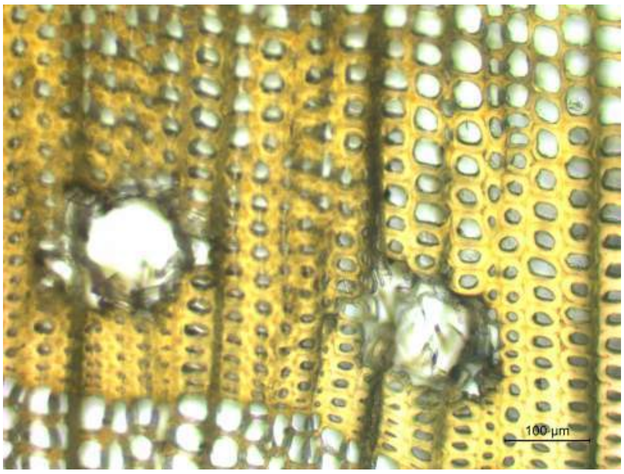


Tangential view

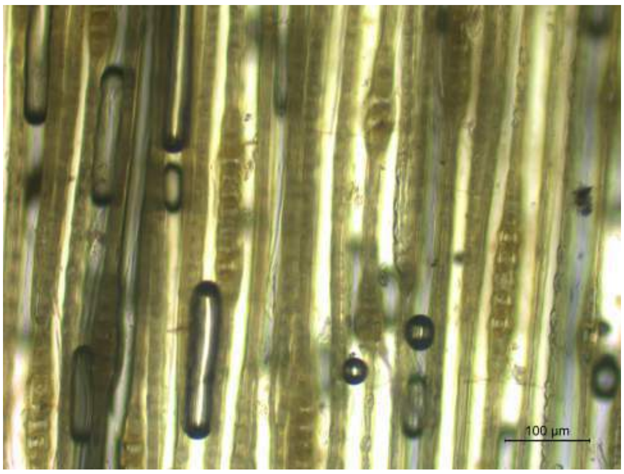
ELEMENT N.13



Radial view

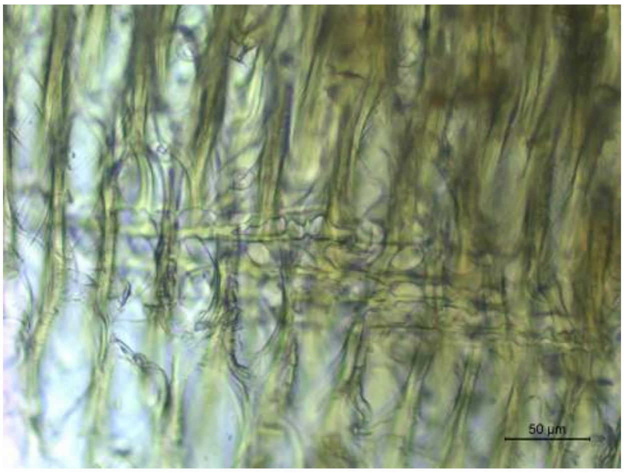


Transversal view

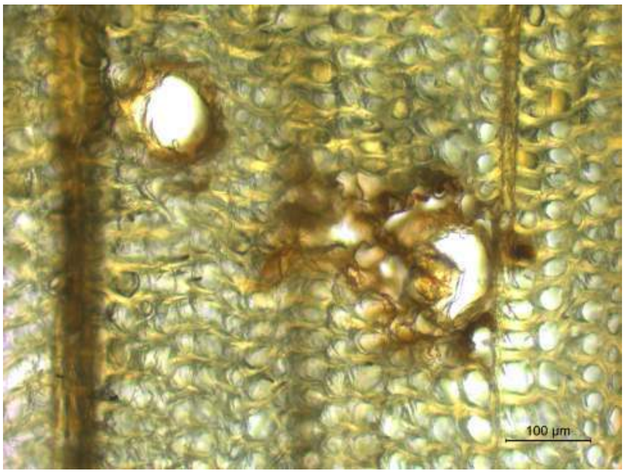


Tangential view

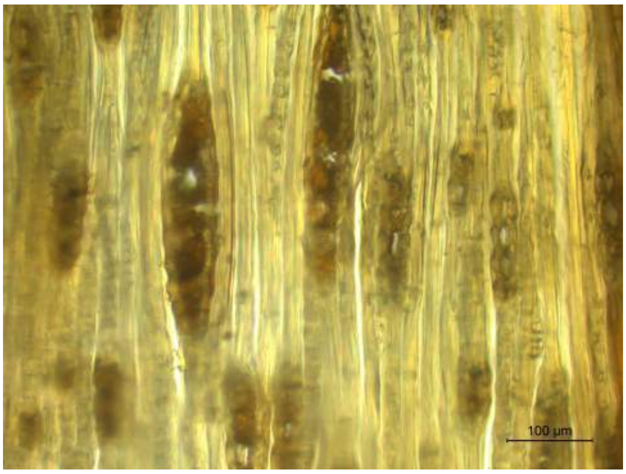
ELEMENT N.14



Radial view



Transversal view



Tangential view

APPENDIX_ B

Code: 1

View side A-B

View side C-D

View side E

View side F

Dimensions:

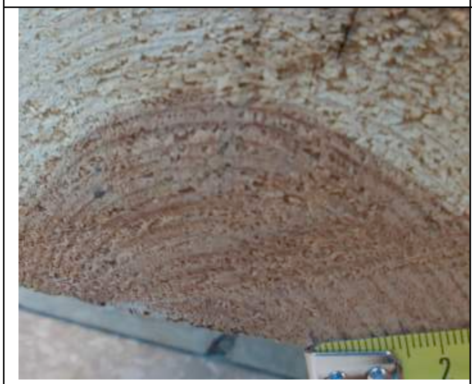
Length: 3,03 m

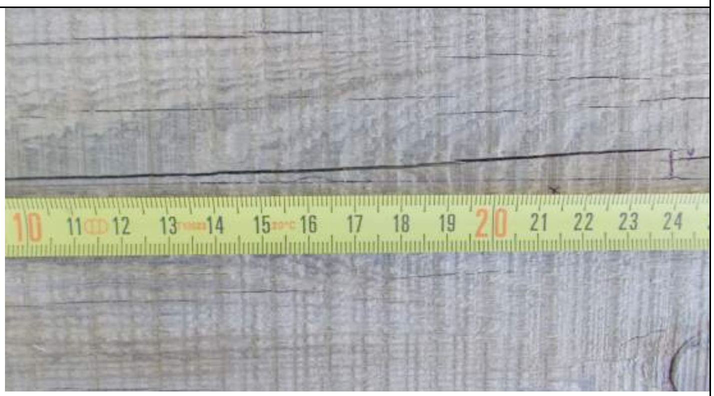
Section 1: 17,5 x 5,7 cm

Section 2: 17,3 x 5,6 cm

Section 3: 17,2 x 5,3 cm

Moisture:	Density:
9,89%	524 Kg/mc
Rate of growth:	**Slope of grain:**
3,0 mm	1 cm length- 0,25 mm height





Knots: N) (x,y) d

Where:

N) reference number of knot

x: x coordinate (cm)

y: y coordinate (cm)

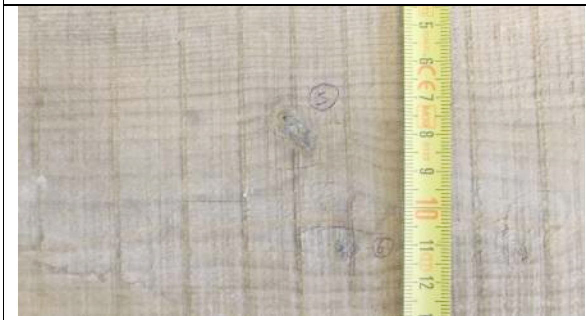
d: diameter measured in a perpendicular direction to the length of the element (cm)

N) (x,y) d + ….+ N^n) (x^n, y^n) d^n = group of knots

N)* = corner knot

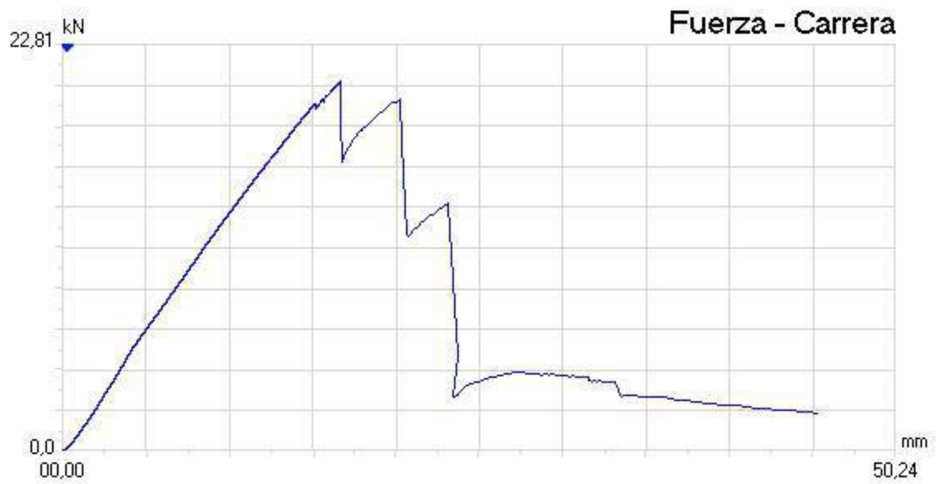
Side A	
knots 6) (88,0 -110,0) 1,3 9) (135,0 -10,0) 1,7 17)* (278,0-14,0) 6,8	*group of knots* 1) (16,5 – 9,0) 1,5 + 2)* (15,0 -10,0) 7 3)* (58,5 -4,5) 7,2 + 4) (61,0 -10,0) 1,3 + 5) (59,5 -14,0) 5,3 7) (116,0 -10,2) 1,2 + 8)° (114,5 -13) 3,5 10) (163,0 -10,0) 3 + 11)* (161,0 -15,0) 3,8 12) (183,0 -11,5) 1,2 + 13) (195,0 -9,0) 1,7 + 14) (195,5 -1,2)1,7 15) (248,0 -8,5) 3,3 + 16) (246,5 -13,0) 6,5
Side B	
knots 18)* (58,5 -2,2) 3,8 19)* (110,5 -4,4) 3,5 20)* (193,7 – 5,2) 1,2 21) (143,7 -2,4) 2,6	*group of knots* not found
Side C	
knots 22) (12,5 -13,5) 3 23) (15,5 -4,5) 1,7 24) (37,0 -2,2) 1,7 25) (83,0 -7,3) 3,2 26) (158,5 -8,4) 2,8 29) (245,0 -11,5) 1,7 30) (277,5 -16,3) 1,2	*group of knots* 27) (182,0 -2,7) 2,2 + 28) (193,0 -10,5) 1,6

Resin pocket: N (x,y) l	
Where: N: reference number of resin pocket x: x coordinate x (cm)	y: y coordinate (cm) l: diameter measured in a parallel direction to the length of the element (mm)

Side A	Side C
1 (88,0 -10) 7 2 (135,0 – 10,0) 7 3 (184,0 -9,2) 5 4 (195,0 -9,0) 7 5 (213,7 -7,7) 11 6 (215,2 -11) 5 7 (281,0 7,7) 10	8 (279,5 -5,3) 12
	
Fissures:	
There are shrinkage cracks, mainly in the centre of the face C and near the corner between the face C and the face D. There are not splits. No shake has a length greater than 1/4 of the length or than 1 meter.	
Ring shakes:	
In the side F there is a multi-ring shake.	
Wane: N^{NM}/ Pc -L ---S	
Where: N: reference number of the wane ^{AB}: borderline sides Pc: centre point calculated with respect to the reference axis y=0 (cm)	L: length of the wane (cm) S: more unfavourable ratio between the projection of the wane on a surface and the total width of the surface.
1^{CD}/ 44 -60 ---0,32 2^{CD}/ 165 -160 ---0,42	

<table>
<tr><th colspan="4">Deformations:</th></tr>
<tr>
<td>Bowing
Measurement with the side C upwards , in the midpoint
5 mm</td>
<td>Crook
Measurement with the side B upwards :
Side E: 8 mm
Side F: 8 mm</td>
<td>Twist
Measurement with the side B upwards :
Side E: 4 mm
Side F: 7 mm
Measurement with the side C upwards :
Side E: 4 mm
Side F: 2 mm</td>
<td>Cupping
Side A concave
Side C convex
1 mm (measurement in the side F)</td>
</tr>
<tr>
<td colspan="2"></td>
<td colspan="2"></td>
</tr>
<tr><th colspan="4">Deterioration:</th></tr>
<tr>
<td colspan="2">Browning of the wood due to UV short wave, evident especially in the side A.</td>
<td colspan="2"></td>
</tr>
<tr><th colspan="4">Other:</th></tr>
<tr><td colspan="4">In the side A there are n.2 holes caused by nails having these coordinates (x,y) : (116,0 – 5); (120,0 – 8,5). In the side B there are n.8 holes caused by nails having these coordinates (x,y): (26,5 -3,0); (57,0 – 2,2); (121,5 -3,3); (153,0 – 2,8); (184,9 -2,8); (216,5 – 3); (249,0 – 2,8); (278,5 – 2,8). In the side B there are n.2 nails having these coordinates (x,y): (89,0 – 3,3); (162,0 – 2,8).</td></tr>
<tr><th colspan="4">Visual grading UNI 11035-2:</th></tr>
<tr><td colspan="4">Wanes: <S3 / Knots (knot 19): S3/ Group of knots (knots 3-4-5): S1 /Rate of growth: S1 / Slope of grain: S1 /Shakes: < S3 / Deterioration: S1/ Insect attack: S1/ Deformations: S1.
Therefore the element n.1, according to this rule, can not be employed for structural uses, due to the presence of the wanes and the ring shakes.</td></tr>
<tr><th colspan="4">Visual grading UNE 56544</th></tr>
<tr><td colspan="4">Knots side A or C: <ME-2 (knots 3-4-5) /knots side B o D: ME-2/ Rate of growth: ME-1 / Shrinkage cracks : ME-1/ Ring shakes: <ME-2/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: <ME-2/ Biological degradation:ME-1/ Deformations: ME-1
Therefore the element n.1, according to this rule, can not be employed for structural uses, due to the presence of the wanes , the ring shakes and the knots 3-4-5.</td></tr>
</table>

BEAM 1-1	
Visual grading UNI 11035-2:	
Wanes : S2 / Knots (knot 19): S3/ Group of knots (knots 3-4-5): S1 / Rate of growth : S1 / Slope of grain : S1 / Shakes : S1 / Deterioration : S1/ Insect attack : S1/ Deformations: S1. Therefore the element n.1-1, according to this rule, has the category S3.	
Visual grading UNE 56544:	
Knots sides A o C: <ME-2 (knots 3-4-5) /knots side B o D: ME-2/ Rate of growth: ME-1 / Shrinkage cracks : ME-1/ Ring shakes: ME-1/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: <ME-2/ Biological degradation:ME-1/ Deformations: ME-1 Therefore the element n.1-1, according to this rule, can not be employed for structural uses, due to the presence of the wanes and the knots 3-4-5.	
Bending strength test:	
Load application side: A The beam breaks in the area of maximum load, near one of two load lines. The knots 3, 5 and 18, even if are located in the compressed part, affect the break, according to the slope of grain which they have caused. The knot 25, located in the upper part, has influence in break mode. However, the knot n.3, located in a corner position, is the most critical point. In the area of maximum load there are not others defects that can affect the break. FORCE-DISPLACEMENT DIAGRAM	



BEAM 1-2

Visual grading UNI 11035-2:

Wanes: <S3 / Knots (knot 21):<S3/ Group of knots (knots 15-16): S1 /Rate of growth: S1 / Slope of grain: S1 /Shakes: < S3 / Deterioration: S1/ Insect attack: S1/ Deformations: S1.

Therefore the element n.1-2, according to this rule, can not be employed for structural uses, due to the presence of the wanes, the ring shake and the knot n.21.

Visual grading UNE 56544

Knots sides A o C: <ME-2 (knots 15-16) /Knots side B o D: ME-1/ Rate of growth: ME-1 / Shrinkage cracks : ME-1/ Ring shakes: <ME-2/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: <ME-2/ Biological degradation:ME-1/ Deformations: ME-1

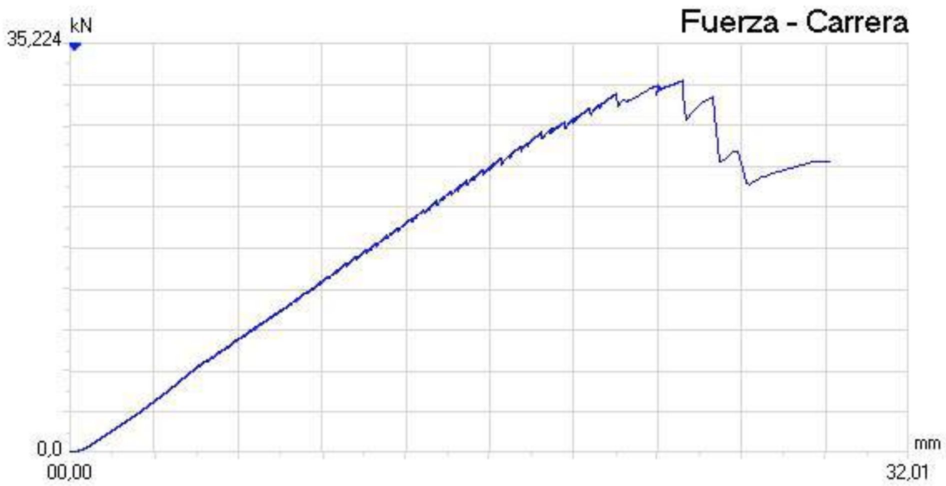
Therefore the element n.1-2, according to this rule, can not be employed for structural uses, due to the presence of the wanes, the ring shake and the knots 15-16.

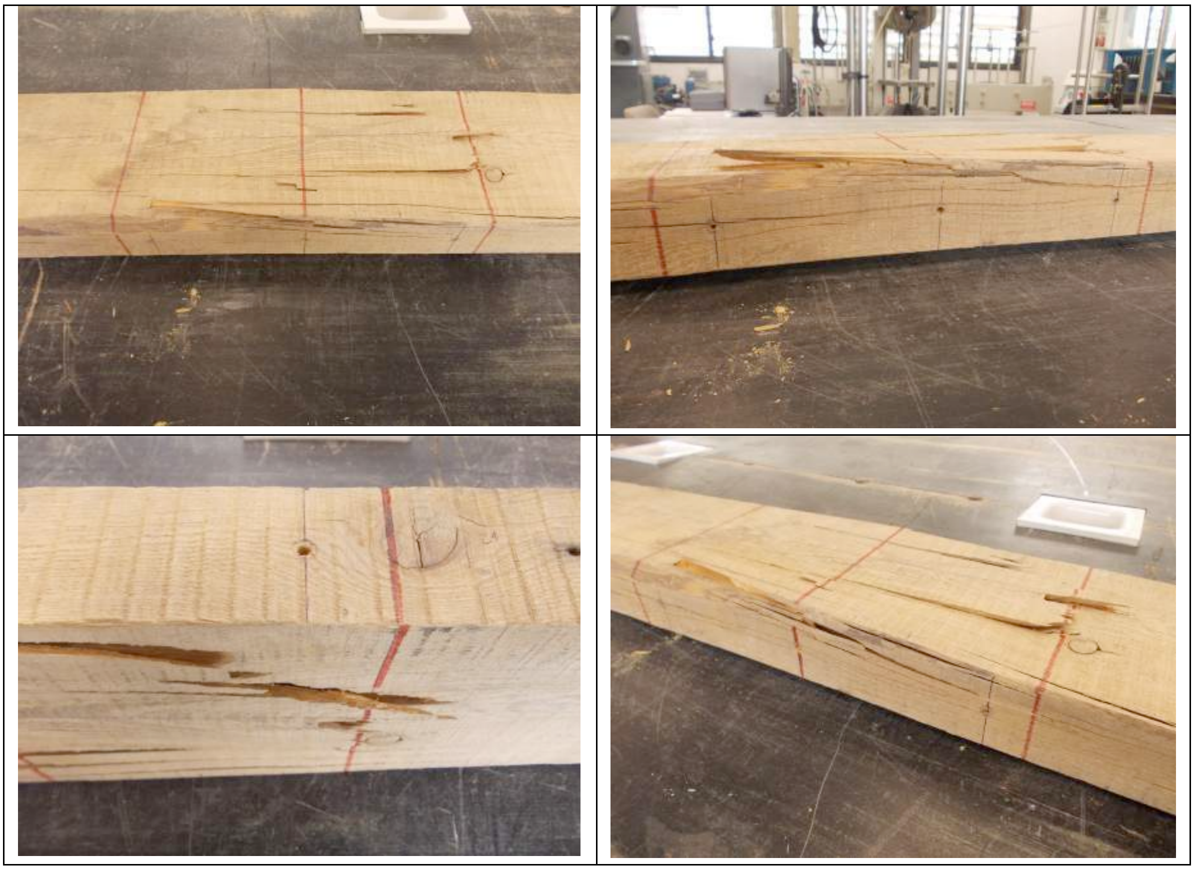
Bending strength test:

Load application side: A

The beam breaks in the area of maximum load. The break follows the slope of grain and is influenced by the presence of the wane between the side C and D and by the knot 29. The knot 21, although located in correspondence of one of the load lines, do not affect the break.

FORCE-DISPLACEMENT DIAGRAM





Code: 2

View side A-B

View side C-D

View side E	View side F
	

Dimensions:

Length: 3,01 m Section 1: 17,0 x 5,8 cm Section 2: 17,1 x 5,8 cm Section 3: 17,4 x 5,8 cm	
Moisture:	**Density:**
9,50%	505 Kg/mc
Rate of growth:	**Slope of grain:**
3,0 mm	1 cm length- 0,49 mm height
	

Knots: N) (x,y) d

Where:

N) reference number of knot

x: x coordinate (cm)

y: y coordinate (cm)

d: diameter measured in a perpendicular direction to the length of the element (cm)

N) (x,y) d + ….+ N^n) (x^n, y^n) d^n = group of knots

N)* = corner knot

Side A	
knots	*group of knots*
1) (19,3 -10,7) 4,1	2) (86,3 -5,7) 1,4 + 3) (89,5 -10,5) 3,6
8) (223,7 -7,7) 5	4)* (121,6 -16,3) 4,2 + 5) (119,5 -4,7) 3
9) (255,0 -9,5) 2,4	6) (191,7 -7,7) 5,2 + 7) (192,5 -15,2) 1,5

Side C	
knots	*Group of knots*
10) (21,7 -7,3) 2,9	11) (42,0 -7,3) 0,8 + 12) (40,5 + 11,6) 1,8
	13) (89,7 -10) 1,7 + 14) (96,5 -8,3) 3
	15) (124,5 -7,8) 3 + 16) (125,3 -10,3) 1,2 + 17)*(124,0 -15,4)4,9
	18)* (254,5 -2,5) 5 + 19) (257,0 -7,5)2,4

Resin pocket: N (x,y) l

Where:

N: reference number of resin pocket

x: x coordinate x (cm)

y: y coordinate (cm)

l: diameter measured in a parallel direction to the length of the element (mm)

Side A	Side C	Side F
1 (256,5 -114,7) 16	3 (19,5 -15,7) 18	5 (5,5 -4) 27
2 (298,0 – 10,7) 7	4 (192,5 -15,0) 8	

Fissures:	
There are shrinkage cracks, mainly in the centre of the face A and near the corner between the face A and the face B. There are shrinkage crack also in the centre of the side C near the end part adjacent to the face F, near the node n. 20. The side D do not present shakes. There are not splits. No shake has a length greater than ¼ of the length or than 1 meter.	 

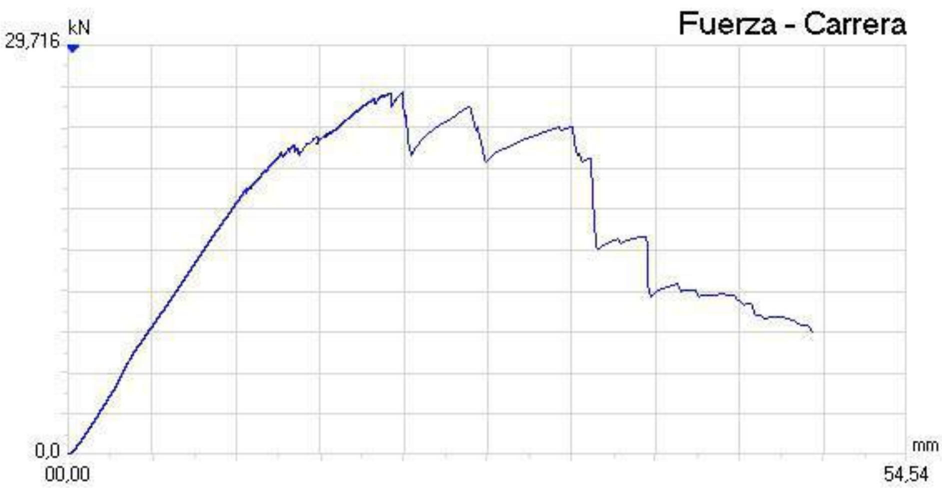
Ring shakes:
Not found.

Wane: N^{NM}/ Pc -L ---S	
Where: N: reference number of the wane ^{AB}: borderline sides Pc: centre point calculated with respect to the reference axis y=0 (cm)	L: length of the wane (cm) S: more unfavourable ratio between the projection of the wane on a surface and the total width of the surface.
1^{AB}/ 7,5 -14,5 ---0,22 2^{AB}/ 54,5 -63,0 + 4^{AD}/ 59,0 -30,0 --- 0,41 3^{AB}/ 126,5 -65,0 ---0,35	

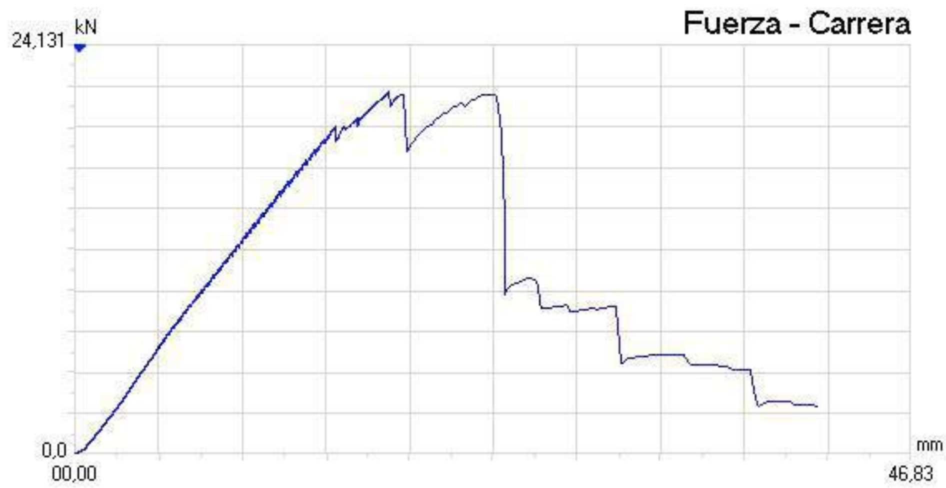
Deformations:			
Bowing Measurement with the side A upwards, found from the midpoint to the side E: 11 mm	Crook Not found	Twist Measurement with the side A upwards: Side F: 3 mm Side E: 5 mm	Cupping Side A convex Side C concave 1 mm (measurement in the side E)

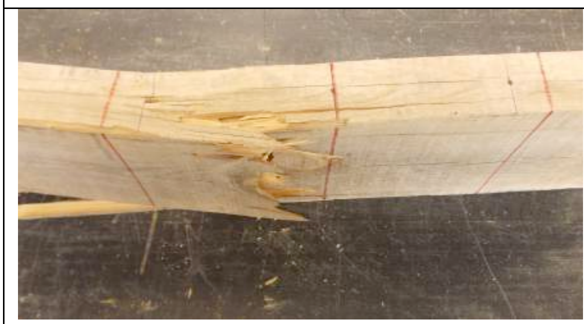
Deterioration:	
Boring of the wood due to UV short wave, evident especially in the side A and in the middle of the side B, near the side A. In the side C there are areas that are grey.	
Other:	
The heartwood, and consequently pith are in a different position between the side E and the side F. In the side A there are n.2 holes caused by nails having these coordinates (x,y) : (123,4 – 8,4); (122,5 – 11,3). In the side B there are n.10 holes caused by nails having these coordinates (x,y): (27,0 -2,6); (56,7 – 3,7); (90,2 -3,0); (121,7 – 3,6); (153,0 -5,3); (185,7 – 2,5); (217,3 – 1,8); (217,7 – 4,7); (248,8 -2,3); (280,0 -3,4). In the side B there is a nail having these coordinate (x,y): (65,3 – 4,7). In the side C there are small shakes due to shocks.	
Visual grading UNI 11035-2:	
Wanes : <S3 / Knots (knot 8): S2/ Group of knots (knots 4-5): S1 / Rate of growth : S1 / Slope of grain : S1 / Shakes : S1 / Deterioration : S1/ Insect attack : S1/ Deformations: S1. Therefore the element n.2, according to this rule, can not be employed for structural uses, due to the presence of the wanes.	
Visual grading UNE 56544	
Knots side A or C: <ME-2 (knots 15-16-17) /knots side B or D: ME-1/ Rate of growth: ME-1 / Shrinkage cracks : ME-1/ Ring shakes: ME-1/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: <ME-2/ Biological degradation:ME-1/ Deformations: ME-1 Therefore the element n.2, according to this rule, can not be employed for structural uses, due to the presence of the wanes and the knots 15-16-17	
BEAM 2-1	
Visual grading UNI 11035-2:	
Wanes : <S3 / Knots (knot 1): S2/ Group of knots (knots 4-5): S1 / Rate of growth : S1 / Slope of grain : S1 / Shakes : S1 / Deterioration : S1/ Insect attack : S1/ Deformations: S1. Therefore the element n.2-1, according to this rule, can not be employed for structural uses, due to the presence of the wanes.	
Visual grading UNE 56544	
Knots side A or C: <ME-2 (knots 15-16-17) /knots side B or D: ME-1/ Rate of growth: ME-1 / Shrinkage cracks : ME-1/ Ring shakes: ME-1/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: <ME-2/ Biological degradation:ME-1/ Deformations: ME-1 Therefore the element n.2-1, according to this rule, can not be employed for structural uses, due to the presence of the wanes and the knots 15-16-17.	

Bending strength test:
Load application side: C The beam breaks in the area of maximum load, in correspondence to the knots 2 and 3. The break follows the slope of the grain and the direction of the break is also conditioned by the nail in the side B. Although in the area of maximum load there are n.2 wanes (n.2 and n. 4), they are not the main cause of the break, despite having conditioned it. FORCE - DISPLACEMENT DIAGRAM



BEAM 2-2
Visual grading UNI 11035-2:
Wanes : S1 / Knots (knot 8): S2/ Group of knots (knots 18-19): S1 / Rate of growth : S1 / Slope of grain : S1 / Shakes : S1 / Deterioration : S1/ Insect attack : S1/ Deformations: S1. Therefore the element n.2-2, according to this rule, has the category S2.
Visual grading UNE 56544
Knots side A or C: ME-2 (knots 18-19) /knots side B or D: ME-1/ Rate of growth: ME-1 / Shrinkage cracks : ME-1/ Ring shakes: ME-1/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: ME-1/ Biological degradation:ME-1/ Deformations: ME-1 Therefore the element n.2-2, according to this rule, has the category ME-2.
Bending strength test:
Load application side: C The beam breaks in the area of maximum load in correspondence to the knot 8, in the middle of this area. There are not others flaws in the area of maximum load. FORCE-DISPLACEMENT DIAGRAM





Code: 3

View side A-B

View side C-D

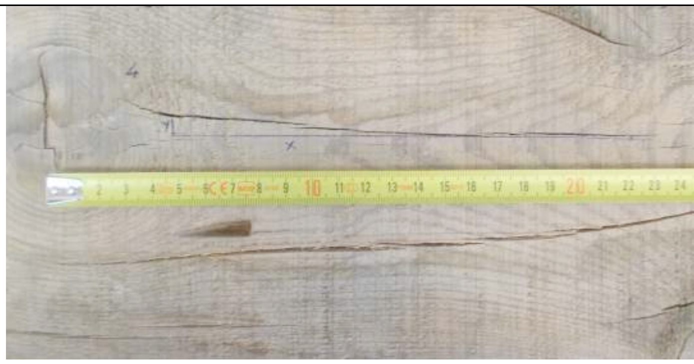
View side E

View side F

Dimensions:

Length: 3,00 m
Section 1: 17,8 x 6,0 cm
Section 2: 17,6 x 6,0 cm
Section 3: 17,5 x 5,8 cm

Moisture:	Density:
9,80%	502 Kg/mc
Rate of growth:	**Slope of grain:**
3,0 mm	1 cm length- 0,32 mm height



Knots: N) (x,y) d

Where:

N) reference number of knot
x: x coordinate (cm)
y: y coordinate (cm)
d: diameter measured in a perpendicular direction to the length of the element (cm)

N) (x,y) d + ….+ N^n) (x^n, y^n) d^n = group of knots
N)* = corner knot

Side A	
knots 1) (12,5 -10,5) 3,1 2) (51,5 -12,5) 7,5 3) (88,0 -6,0) 3,3 4) (125,5 -8,5) 5,9 7) (183,0 -7,7) 1,8 10) (239,0 -10,8) 4,5	*group of knots* 5) (147,5 -4,0)3,5 + 6)* (153,5 -16,7)3,5 8)* (211,5 -1,5) 2,7 + 9) (208,5 -10,1) 2 11)* (280,5 -2,5) 5 + 12) (283,0 -12,8)3
Side B	
knots 13)* (33,5 -4,5) 3,5 14)*(207,8 -2,4) 4,7	*group of knots* not found
Side C	
knots 17) (54,8 -8,2) 4,2 18) (90,5 -10) 2,1 19) (108,5 -11,7)3,1 20) (128,0 -8,7) 2,2 23) (212,5 -7,0) 1,6 24) (240,5 -11,0) 2,4 25)* (282,0 -3,0) 7,0	*group of knots* 15) (15,2 -8,5) 2,2 +16)* (12,0 -15,5) 5,5 21) (156,0 -6,2) 2,0 + 22) (155,0 -8,4) 1,6
Side D	
knots 26)* (105,0 -4,2) 4,0 27) (236,7 -3,3) 1,8	*group of knots* not found

Resin pocket: N (x,y) l

Where:

N: reference number of resin pocket

x: x coordinate x (cm)

y: y coordinate (cm)

l: diameter measured in a parallel direction to the length of the element (mm)

Side A	Side B
1 (13,5 -10,0) 12	2 (34,2 -4,0) 16
Side C	**Side D**
3 (68,0 -5,2) 72	4 (105,0 -5,0) 32

Fissures:

There are shrinkage cracks, mainly in the centre of the face A, in the face B near the corner between the face A from the middle to the face F. In the middle of the side D there are shakes, conditioned to the nails that are in these shakes.

There are not splits. No shake has a length greater than 1/4 of the length or than 1 meter.

Ring shakes:

Not found.

Wane: N^{NM}/ Pc -L ---S

Where:

N: reference number of the wane

^{AB}: borderline sides

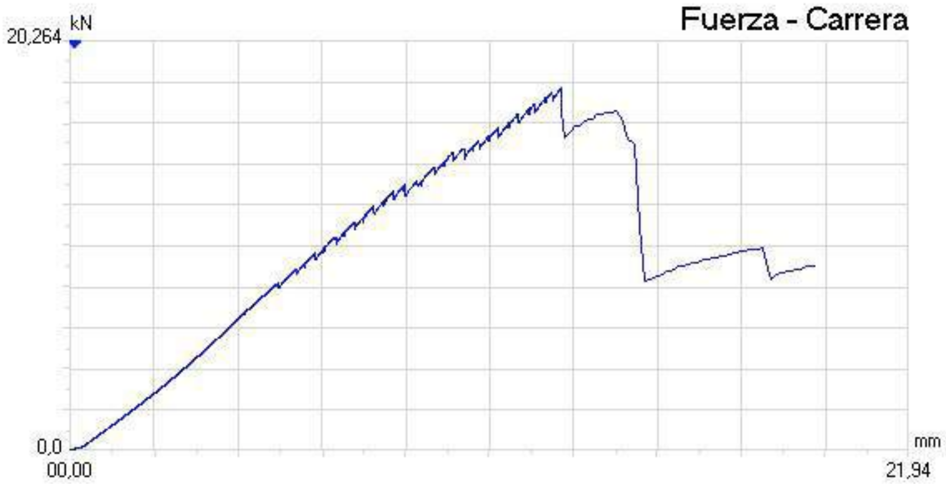
Pc: centre point calculated with respect to the reference axis y=0 (cm)

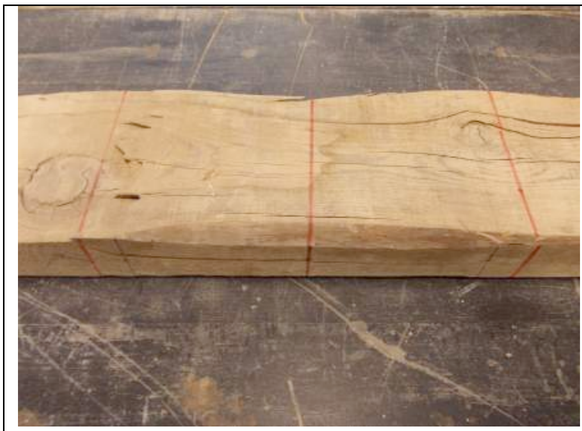
L: length of the wane (cm)

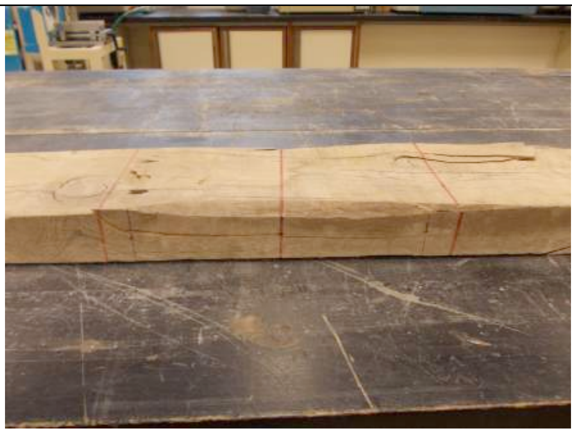
S: more unfavourable ratio between the projection of the wane on a surface and the total width of the surface.

<table>
<tr><td colspan="2">1^{AB}/ 15,0 -30,0 + 2^{AD}/ 25,0 -32,0 ---0,47
3^{AB}/ 77,0 -40,0 + 4^{AD}/ 93,0 -62,0 --- 0,63</td><td colspan="2"></td></tr>
<tr><td colspan="4">Deformations:</td></tr>
<tr><td>Bowing
Not found</td><td>Crook
Not found</td><td>Twist
Measurement with the side A upwards
Side F: 3 mm
Side E: 2 mm</td><td>Cupping
Side A convex
Side C concave
3 mm (measurement in the side F)</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="4">Deterioration:</td></tr>
<tr><td colspan="2">Browning of the wood due to UV short wave and blots, evident especially in the side A and D and right in the middle of side B.</td><td colspan="2"></td></tr>
<tr><td colspan="4">Other:</td></tr>
<tr><td colspan="4">In the side A there is n. 1 hole caused by nails having these coordinates (x,y) : (129,3 – 3,9) and a triangular crack having these coordinates (x,y): (132,5 – 12,5).
In the side C there are trail of mortar and n.2 holes caused by nails having these coordinates (x,y): (128,5 -9,5); (130,0 -14,0).
In the side D there are n.12 holes caused by nails having these coordinates (x,y): (2,2 -2,7); (33,3 – 3,0); (33,8 -1,4); (63,3 – 2,4); (64,3 -3,8); (96,3 – 2,8); (128,3 – 2,6); (160,3 – 2,6); (192,3 -3,3); (223,6 -2,6); (254,3 -2,6); (286,0 -2,6).</td></tr>
<tr><td colspan="4">Visual grading UNI 11035-2:</td></tr>
<tr><td colspan="4">Wanes: <S3 / Crack: S1/ Knots (knot 14): S3/ Group of knots (knots 5-1): S1 /Rate of growth: S1 / Slope of grain: S1 /Shakes: S1 / Deterioration: S1/ Insect attack: S1/ Deformations: S1.
Therefore the element n.3, according to this rule, can not be employed for structural uses, due to the presence of the wanes.</td></tr>
</table>

Visual grading UNE 56544
Knots side A or C: ME-2 / Knots side B or D: <ME-2 (nodo 14)/ Rate of growth: ME-1 / Shrinkage cracks : ME-1/ Ring shakes: ME-1/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: <ME-2/ Biological degradation:ME-1/ Deformations: ME-1 Therefore the element n.3, according to this rule, can not be employed for structural uses, due to the presence of the wanes and the knots 14.
BEAM 3-1
Visual grading UNI 11035-2:
Wanes: <S3 / Crack: S1/ Knots (knot 13): S3/ Group of knots (knots 15-16): S1 /Rate of growth: S1 / Slope of grain: S1 /Shakes: S1 / Deterioration: S1/ Insect attack: S1/ Deformations: S1. Therefore the element n.3-1, according to this rule, can not be employed for structural uses, due to the presence of the wanes.
Visual grading UNE 56544
Knots side A or C: ME-2 /Knots side B or D: ME-2/ Rate of growth: ME-1 / Shrinkage cracks: ME-1/ Ring shakes: ME-1/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: <ME-2/ Biological degradation:ME-1/ Deformations: ME-1 Therefore the element n.3-1, according to this rule, can not be employed for structural uses, due to the presence of the wanes.
Bending strength test:
Load application side: C The beam breaks in the area of maximum load, corresponding to the knots 2 and 3 and out of the area of maximum load corresponding to the knot 26. The knots 2, 3 and 26 deviate the grain, preventing to assume a horizontal course, behave like a group of knots. The break is influenced by the wanes and the shrinkage cracks, that are in the area of maximum load. In the sides D and D, the direction of the break is horizontal. FORCE-DISPLACEMENT DIAGRAM







BEAM 3-2

Visual grading UNI 11035-2:

Wanes: S1 / Crack: S1/ Knots (knot 14): S3/ Group of knots (knots 5-6): S1 /Rate of growth: S1 / Slope of grain: S1 /Shakes: S1 / Deterioration: S1/ Insect attack: S1/ Deformations: S1.
Therefore the element n.3-2, according to this rule, has the category S3.

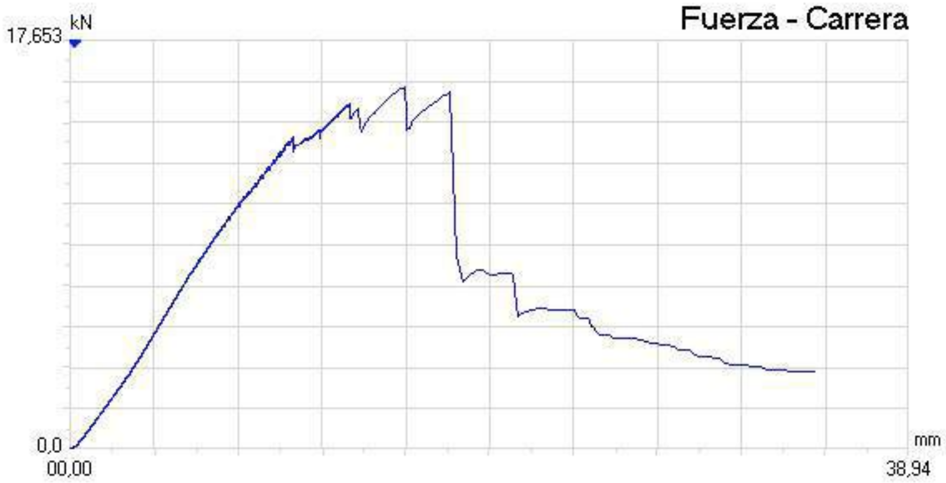
Visual grading UNE 56544

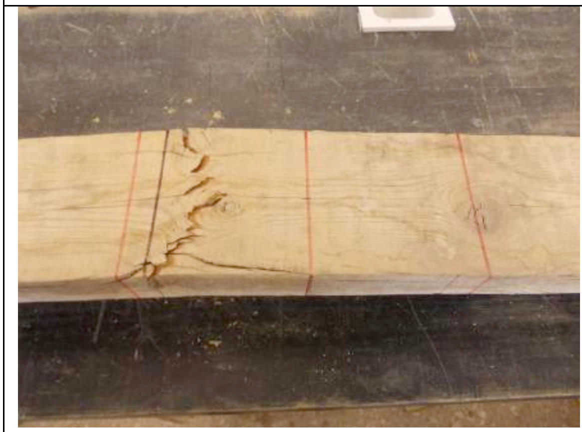
Knots side A or C: ME-2 /Knots side B or D: <ME-2 (knot 14)/ Rate of growth: ME-1 / Shrinkage cracks: ME-1/ Ring shakes: ME-1/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: ME-1/ Biological degradation:ME-1/ Deformations: ME-1
Therefore the element n.3-2, according to this rule, can not be employed for structural uses, due to the presence of the knots 14.

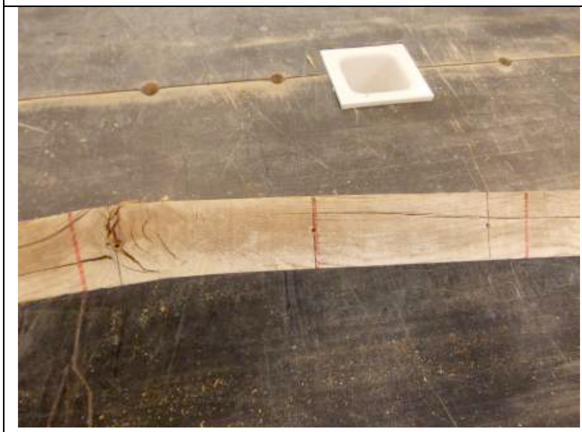
Bending strength test:

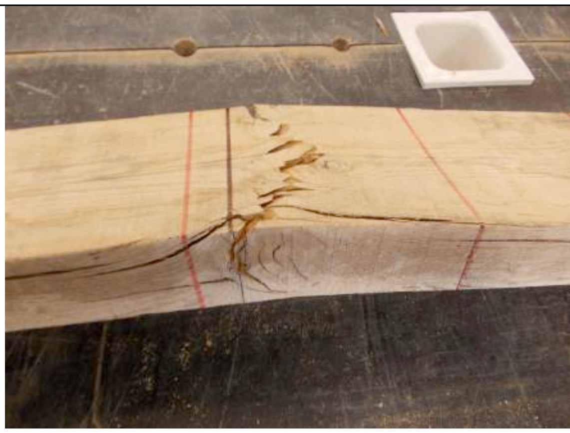
Load application side: C
The beam breaks in the area of maximum load, corresponding to the knots 8,9 and 14, according to the slope of grain. These knots are located on a load line and they are they are aligned along the section of the beam. The knots 10 and 27 although located corresponding to one of the load lines, do not affect the break.

FORCE-DISPLACEMENT DIAGRAM









Code: 4

View side A-B

View side C-D

View side E

View side F

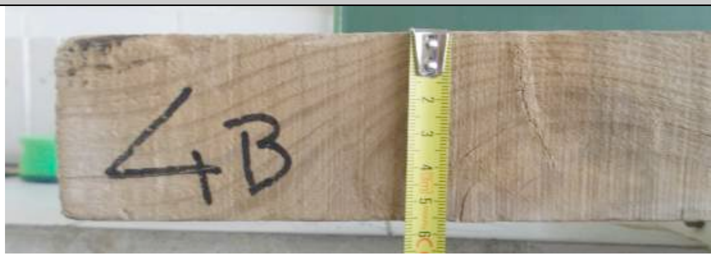
Dimensions:

Length: 3,01 m

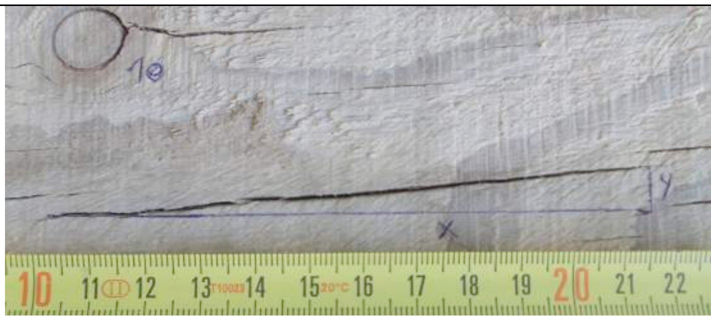
Section 1: 17,5 x 5,6 cm

Section 2: 17,5 x 5,8 cm

Section 3: 17,2 x 5,6 cm



Moisture:	Density:
10,20 %	520 Kg/mc
Rate of growth:	**Slope of grain:**
4,0 mm	1 cm di length- 0,78 mm height



Knots: N) (x,y) d

Where:

N) reference number of knot

x: x coordinate (cm)

y: y coordinate (cm)

d: diameter measured in a perpendicular direction to the length of the element (cm)

N) (x,y) d + ….+ N^n) (x^n, y^n) d^n = group of knots

N)* = corner knot

Side A	
knots 1)* (23,5 -1,5) 4,0 11) (211,5 -10,8) 4,5	*group of knots* 2) (53,5 -11,2)5,5 + 3) (71,4 -7,4) 5,3 4) (101,5 -6,9) 1,6 + 5) (121,6 -7,9) 4,1 6) (144,7 -4,8) 4,7 + 7) (146,3 -15,7) 1,2 8) (171,6 -12,7) 4,4 + 9) (163,0 -15,2) 1,6 +10) (188,0 -9,5) 1,1
Side B	
knots 12)* (102,0 -1,0) 5,0 13) (187,8 -3,7) 4,0 14)* (244,5 -0,5) 3,0 15)* (276,5 -0,5) 3,5 16)* (296,8 -5,0) 1,4	*group of knots*
Side C	
knots 17) (31,0 -12,5) 1,0 18) (61,0 -8,0) 2,0 35) (281,5 -5,0) 1,5	*group of knots* 19) (78,0 -9,5) 1,7 + 20) (80,2 -3,0) 1,2 21) (110,0 -5,7) 1,7 + 22)* (121,4 -0,5) 2,5 + 23) (125,0 -11,6) 2,0 24) (148,6 -5,5) 1,0 + 25) (148,0 -10,1) 1,7 26)* (171,0 -14,5) 2,0 + 27) (172,0 -7,0) 1,0 28) (191,3 -3,7) 1,4 + 29) (192,2 -8,2) 1,2 30) (250,5 -5,0)2,5+31)(216,5 -8,2) 2,5+32)(217,5-2,0) 0,8 33)(250,5-5,0)2,5 + 34)* (254,2 -15,5) 2,1
Side D	
knots 36) (27,5 –1,7) 0,5 37)* (166,2 -1,7) 1,5 38) (206,2 -3,7) 1,0 39)* (241,7 -1,0) 2,0	*group of knots*
	

<table>
<tr><th colspan="4">Resin pocket: N (x,y) l</th></tr>
<tr><td colspan="2">Where:
N: reference number of resin pocket
x: x coordinate x (cm)</td><td colspan="2">y: y coordinate (cm)
l: diameter measured in a parallel direction to the length of the element (mm)</td></tr>
<tr><th colspan="2">Side B</th><th colspan="2">Side C</th></tr>
<tr><td colspan="2">1 (108,0 -2,5) 11</td><td colspan="2">2 (113,2 -9,5) 6
3 (285,0 -10,5) 10</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><th colspan="4">Fissures:</th></tr>
<tr><td colspan="2">There are shrinkage cracks, mainly in the face A and in the extremity of the side E. There are not splits. No shake has a length greater than 1/4 of the length or than 1 meter.</td><td colspan="2"></td></tr>
<tr><th colspan="4">Ring shakes:</th></tr>
<tr><td colspan="4">Not found</td></tr>
<tr><th colspan="4">Wane:</th></tr>
<tr><td colspan="4">Not found</td></tr>
<tr><th colspan="4">Deformations:</th></tr>
<tr><td>Bowing
Not found</td><td>Crook
Not found</td><td>Twist
Measurement with the side A upwards
Side E: 5 mm
Side F: 4 mm</td><td>Cupping
Side A convex
Side C concave
2 mm (measurement in the side F)</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
</table>

Deterioration:

Browning of the wood due to UV short wave and blots, evident especially in the sides A, B, D and F. In the side E there are trails of mildew.

Other:

Between the side A and the side E there is a crack, due to shock. In the side A there are n.2 holes caused by nails having these coordinates (x,y): (255,0 – 15,1) (258,3 -10,5) and n.3 nails having these coordinates (x,y): (4,0 – 8,0); (2,5- 10,7); (9,7 -14,0). In the side C there are n.2 holes caused by nails having these coordinates (x,y): (254,7 – 3,5) (258,7 -7,7) and n.1 nails having these coordinates (x,y): (8,5 – 5,0). In the side D there are n.1 nail having these coordinate (x,y): (33,5 -2,7) and n.14 holes caused by nails having these coordinates (x,y): (34,7 -0,7); (66,1 -4,3); (67,0 -1,4); (98,5 -2,7); (130,2 -4,3); (129,2 – 1,4); (162,0 -3,3); (162,3 -0,3); (191,7 -2,7); (224,0 -2,4); (225,2 -4); (255,7 -3,8); (287,7 – 4,7); (288,3 -1,7).

Visual grading UNI 11035-2:

Wanes: S1 / Knots (knot 13): <S3/ Group of knots (knots 2-3): S2 /Rate of growth: S1 / Slope of grain: S2 /Shakes: S1 / Deterioration: S1/ Insect attack: S1/ Deformations: S1.

Therefore the element n.4, according to this rule, can not be employed for structural uses, due to the presence of the knot n.13.

Visual grading UNE 56544:

Knots sides A o C: <ME-2 (knots 2-3) /knots side B o D: <ME-2 (knot 12)/ Rate of growth: ME-1/ Shrinkage cracks : ME-1/ Ring shakes: ME-1/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: ME-1/ Biological degradation:ME-1/ Deformations: ME-1

Therefore the element n.4, according to this rule, can not be employed for structural uses, due to the presence of the knots 2-3 and 12.

BEAM 4-1

Visual grading UNI 11035-2:

Wanes: S1 / Knots (knot 12): <S3/ Group of knots (knots 2-3): S2 /Rate of growth: S1 / Slope of grain: S2 /Shakes: S1 / Deterioration: S1/ Insect attack: S1/ Deformations: S1.

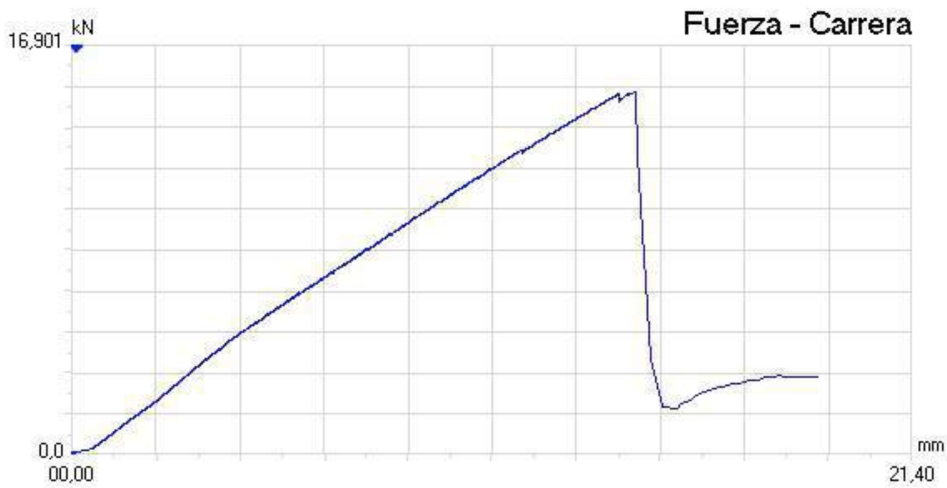
Therefore the element n.4-1, according to this rule, can not be employed for structural uses, due to the presence of the knot n.12.

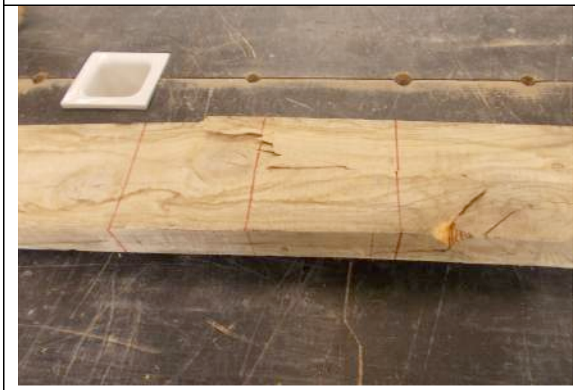
Visual grading UNE 56544

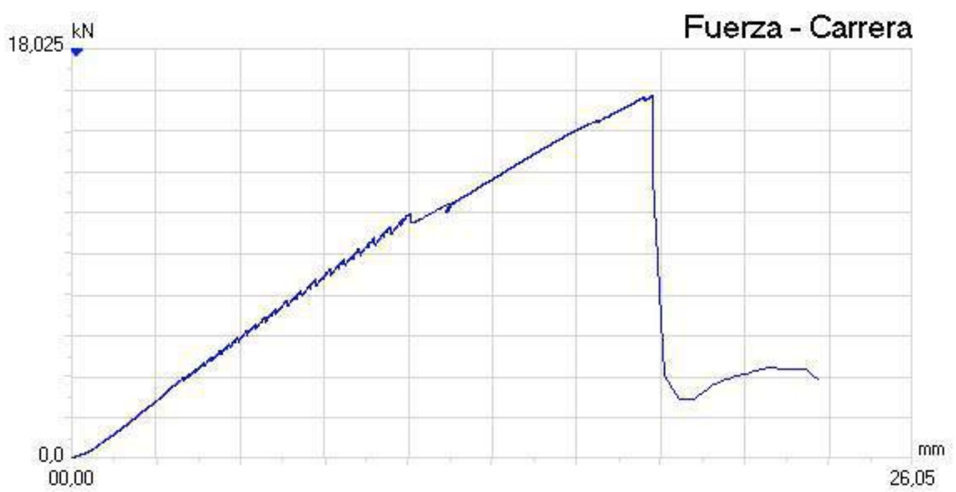
Knots side A or C: <ME-2 (knots 2-3) /knots side B or D: <ME-2 (knot 12) / Rate of growth: ME-1/ Shrinkage cracks : ME-1/ Ring shakes: ME-1/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: ME-1/ Biological degradation:ME-1/ Deformations: ME-1

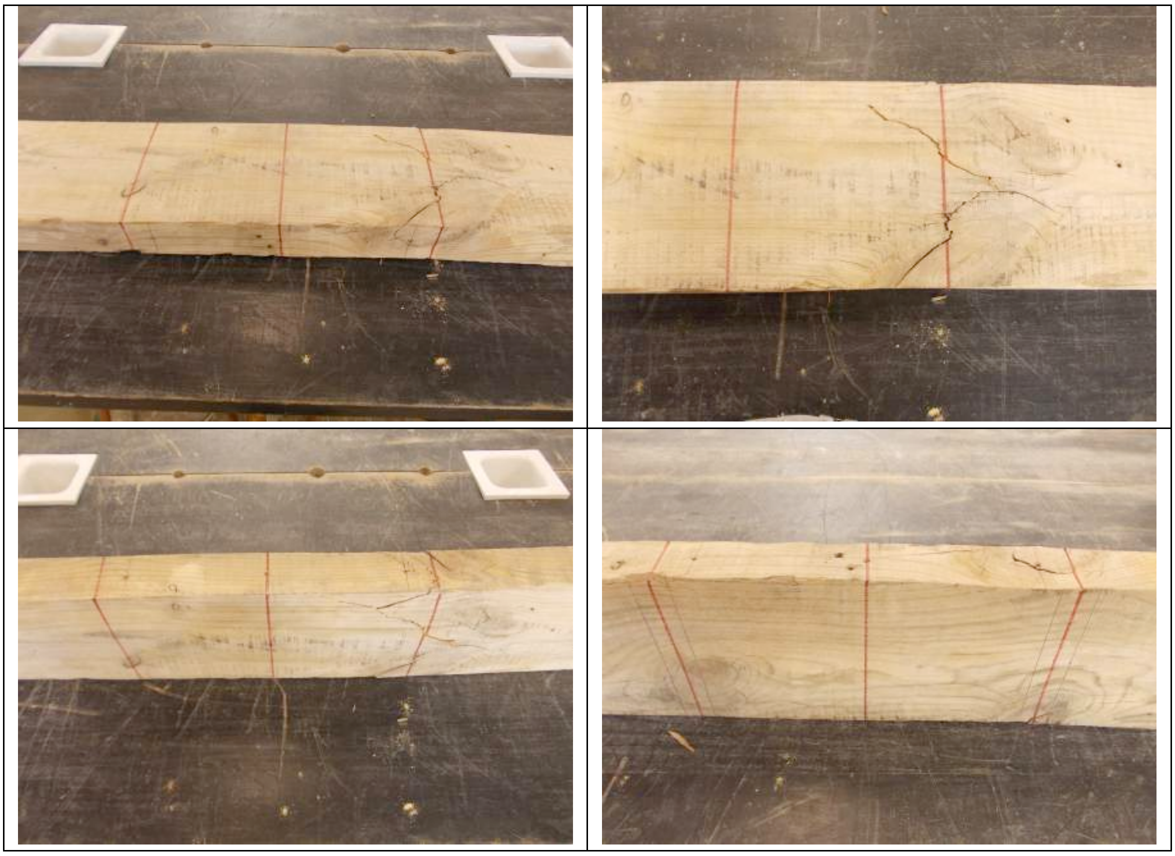
Therefore the element n.4-1, according to this rule, can not be employed for structural uses, due to the presence of the knots 2-3 and 12.

Bending strength test:
Load application side: C The beam breaks in the area of maximum load, corresponding to the knot 3, that is right in the middle. The beam breaks also out of the area of maximum load, corresponding to the knot 12. The knot 2 even more adjacent to the area of maximum load than the knot 12 do not cause the break. The break does not follow the slope of grain. FORCE-DISPLACEMENT DIAGRAM






BEAM 4-2
Visual grading UNI 11035-2:
Wanes: S1 / Knots (knot 13): <S3/ Group of knots (knots 33-34): S2 /Rate of growth: S1 / Slope of grain: S2 /Shakes: S1 / Deterioration: S1/ Insect attack: S1/ Deformations: S1. Therefore the element n.4-2, according to this rule, can not be employed for structural uses, due to the presence of the knot 13.
Visual grading UNE 56544:
Knots side A or C: ME-2 /knots side B or D: <ME-2 (knot 13)/ Rate of growth: ME-1 / Shrinkage cracks : ME-1/ Ring shakes: ME-1/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: ME-1/ Biological degradation:ME-1/ Deformations: ME-1 Therefore the element n.4-2, according to this rule, can not be employed for structural uses, due to the presence of the knot 13.
Bending strength test:
Load application side: A The beam breaks near the area of maximum load, corresponding to the knots 24 and 39, and the corner knot between the side C and the side D. The break line is between the knot 14, knot 33 and knot 34 and it follows a direction different from the grain, although conditioned by these knots. FORCE-DISPLACEMENT DIAGRAM




Code: 5

View side A-B

View side C-D

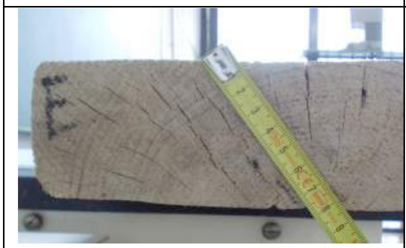
View side E

View side F

Dimensions:

Length: 3,00 m
Section 1: 17,9 x 6,0 cm
Section 2: 17,9 x 6,0 cm
Section 3: 17,7 x 5,9 cm

Moisture:	Density:
10,40%	486 Kg/mc
Rate of growth:	**Slope of grain:**
1,2 mm	1 cm di length- 0,09 mm height



Knots: N) (x,y) d

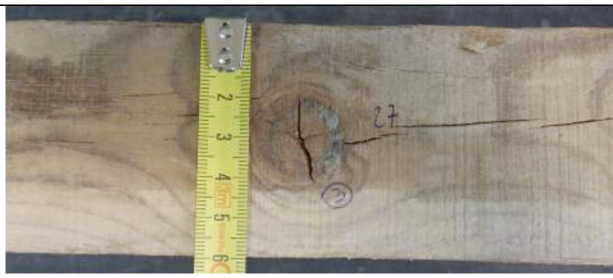
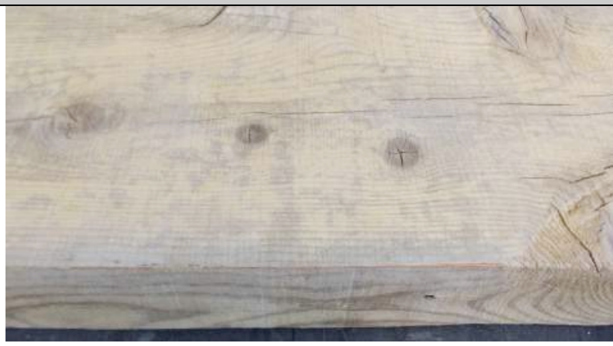
Where:

N) reference number of knot
x: x coordinate (cm)
y: y coordinate (cm)
d: diameter measured in a perpendicular direction to the length of the element (cm)

N) (x,y) d + ….+ N^n) (x^n, y^n) d^n = group of knots
N)* = corner knot

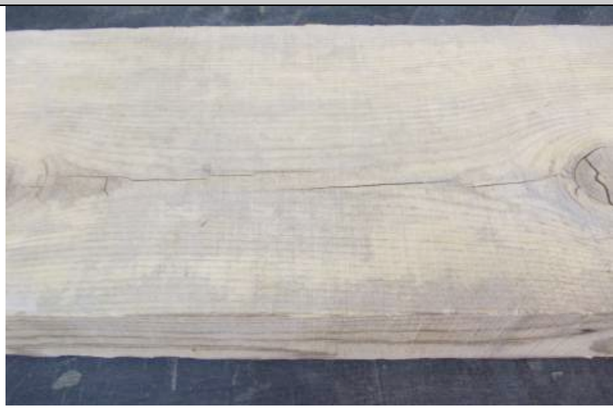
Side A	
knots 1) (11,1 -8,0) 5,5 2) (43,7 -9,0) 5,5 3) (78,1 -11,3) 3,7 4) (107,8 -11) 4,0 5)* (129,5 -0,0) 6,5	*group of knots* 6) (206,2 -11,5) 4,3 + 7) (217, 2-9,8) 2,8 + 8) (225,2 -10,5) 1,6 + 9)(232,2 -11,7) 2,2 + 10)* (240,5 -0,0) 5,0 + 11)* (243,2 -15,5) 6,3 + 12) (249,2 -8,5) 2,8 + 13) (260,5 -4,6) 4,7 + 14 (272,2 – 7,7) 2,8
Side B	
knots 15) (15,1 -2,5) 3,9 16) (128,7 -4,6) 1,0	*group of knots*
Side C	
knots 19) (48,5 -7,2) 1,5 23) (217,5 -3,4) 3,8 24) (263,8 -13) 4,5	*group of knots* 17) (16,0 -4,4) 2,0 + 18) (15,0 -7,3) 1,7 20) (191,6 -5,7) 2,9 + 21) (192,0 -8,0) 1,8 + 22) (203,4 -10,0) 1,4
Side D	
knots 25) (109,5 -3,7) 0,8 26)* (162,0 -4,0) 4,5 27) (199,3 -3,0) 2,5 28) (227,0 -3,5) 3,7 29) (242,5 -1,5) 1,2 30) (286,7 -1,5) 2,5	*group of knots*

Resin pocket: N (x,y) l	
Where: N: reference number of resin pocket x: x coordinate x (cm)	 y: y coordinate (cm) l: diameter measured in a parallel direction to the length of the element (mm)

<table>
<tr><th colspan="2">Side C</th><th colspan="2">Side D</th></tr>
<tr><td colspan="2">1 (48,5 -12,0) 5
2 (187,7 -2,7) 10</td><td colspan="2">3 (200,3 -3,0) 5</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><th colspan="4">Fissures:</th></tr>
<tr><td colspan="2">There are shrinkage cracks, mainly in the middle of the sides A, B and C. In the side C the shakes have a more regular trend because there are fewer nodes. In the side D there are shakes near the knots. The side E has numerous small spiral cracks converging to the pith. There is also a crack caused by a nail in the side B, with coordinate (x,y): (265,5-1,5). There are not splits. No shake has a length greater than 1/4 of the length or than 1 meter.</td><td colspan="2">
</td></tr>
<tr><th colspan="4">Ring shakes:</th></tr>
<tr><td colspan="4">Not found</td></tr>
<tr><th colspan="4">Wane:</th></tr>
<tr><td colspan="4">Not found</td></tr>
<tr><th colspan="4">Deformations:</th></tr>
<tr><td>Bowing
Measurement with the side A upwards:
Extremity side E: 6 mm
Extremity side F: 11 mm</td><td>Crook
Measurement with the side B upwards, right in the middle:
5 mm.</td><td>Twist
Measurement with the side A upwards:
Side E: 2 mm
Side F: 6 mm</td><td>Cupping
Side A convex
Side C concave
1 mm (measurement in the side F)</td></tr>
</table>


Deterioration:

Browning of the wood due to UV short wave and , evident especially right in the middle of side C.



Other:

In the side F there is the pith. In the side A there are n.1 nail having these coordinates (x,y): (5,0 – 9,0) and n.2 holes caused by nails having these coordinates (x,y): (264,2 -6,3); (265,0 -1,8). In the side B there are n.2 nails having these coordinates (x,y): (200,2 -3,5); (265,5 -1,5) and n. 8 holes caused by nails having these coordinates (x,y): (41,0 -3,0); (75,1 -2,3); (106,3 -2,2); (137,8 -2,1); (170,0 -2,6); (200,8 – 1,3); (233,2 -2,7); (296,2 -3,1).

Visual grading UNI 11035-2:

Wanes: S1 / Knots (knot 26): <S3/ Group of knots (knots 6-7-8-9-10-11-12-13-14): <S3 /Rate of growth: S2 / Slope of grain: S1 /Shakes: S1 / Deterioration: S1/ Insect attack: S1/ Deformations: S1.

Therefore the element n.5, according to this rule, can not be employed for structural uses, due to the presence of the knots n. 6-7-8-9-10-11-12-13-14.

Visual grading UNE 56544:

Knots side A or C: <ME-2 (knots 6-7-8-9-10-11-12-13-14) /knots side B or D: <ME-2 (knot 26)/ Rate of growth: ME-1 / Shrinkage cracks : ME-1/ Ring shakes: ME-1/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: ME-1/ Biological degradation:ME-1/ Deformations: ME-1

Therefore the element n.5, according to this rule, can not be employed for structural uses, due to the presence of the knots n. 6-7-8-9-10-11-12-13-14 and 26.

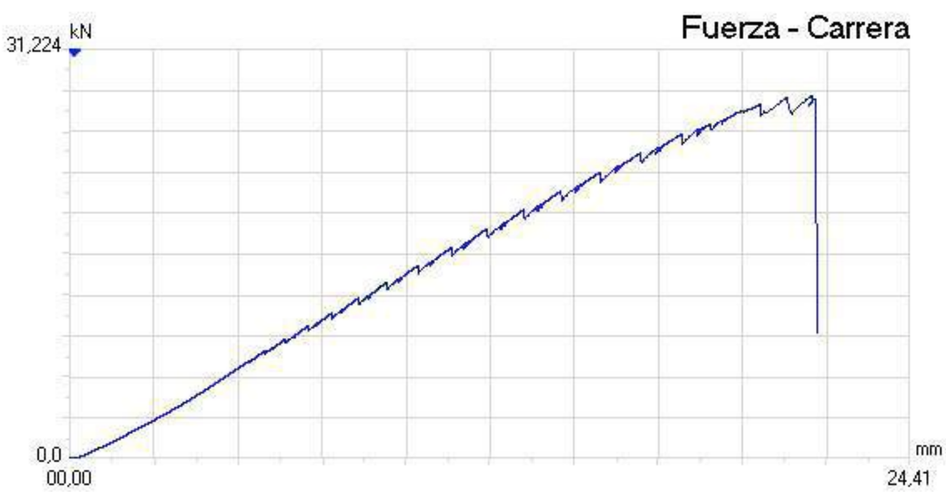
TRAVE 5-1

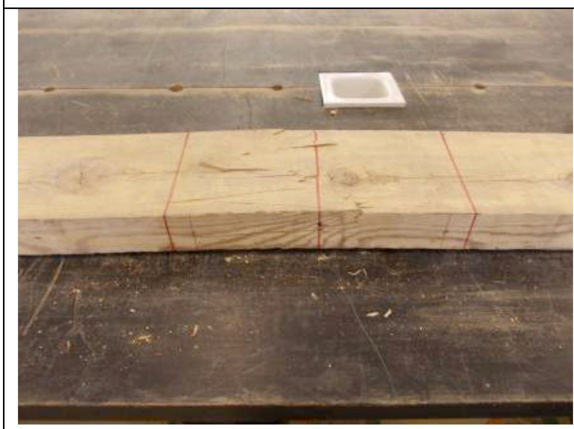
Visual grading UNI 11035-2:

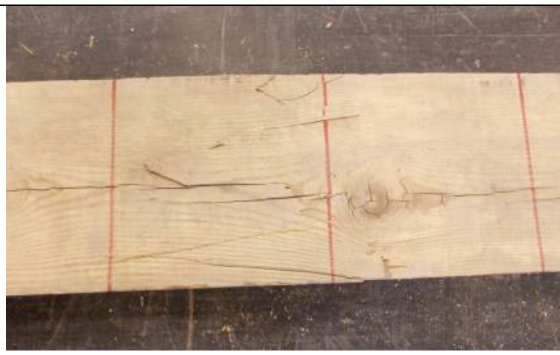
Wanes: S1 / Knots (knot 4): S2/ Group of knots (knots 17-18): S1 /Rate of growth: S2 / Slope of grain: S1 /Shakes: S1 / Deterioration: S1/ Insect attack: S1/ Deformations: S1.

Therefore the element n.5-1, according to this rule, has the category S2.

Visual grading UNE 56544:
Knots side A or C: ME-2 /knots side B or D: ME-2/ Rate of growth: ME-1 / Shrinkage cracks : ME-1/ Ring shakes: ME-1/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: ME-1/ Biological degradation:ME-1/ Deformations: ME-1 Therefore the element n5-1, according to this rule, has the category ME-2.
Bending strength test :
Load application side: C The beam breaks in the area of maximum load, right in the middle, corresponding to the knot 3 and the shakes near this knot. The break line follows the slope of grain partially. In the area of maximum load there are not others defects that can affect the break. FORCE-DISPLACEMENT DIAGRAM







TRAVE 5-2

Visual grading UNI 11035-2:

Wanes: S2 / Knots (knot 26): <S3/ Group of knots (knots 6-7-8-9-10-11-12-13-14): <S3 /Rate of growth: S2 / Slope of grain: S1 /Shakes: S1 / Deterioration: S1/ Insect attack: S1/ Deformations: S1.

Therefore the element n.5-2, according to this rule, can not be employed for structural uses, due to the presence of the knots 6-7-8-9-10-11-12-13-14 and 26.

Visual grading UNE 56544:

Knots side A or C: <ME-2 (knots 6-7-8-9-10-11-12-13-14) /knots side B or D: <ME-2 (knot 26)/ Rate of growth: ME-1 / Shrinkage cracks : ME-1/ Ring shakes: ME-1/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: ME-1/ Biological degradation:ME-1/ Deformations: ME-1

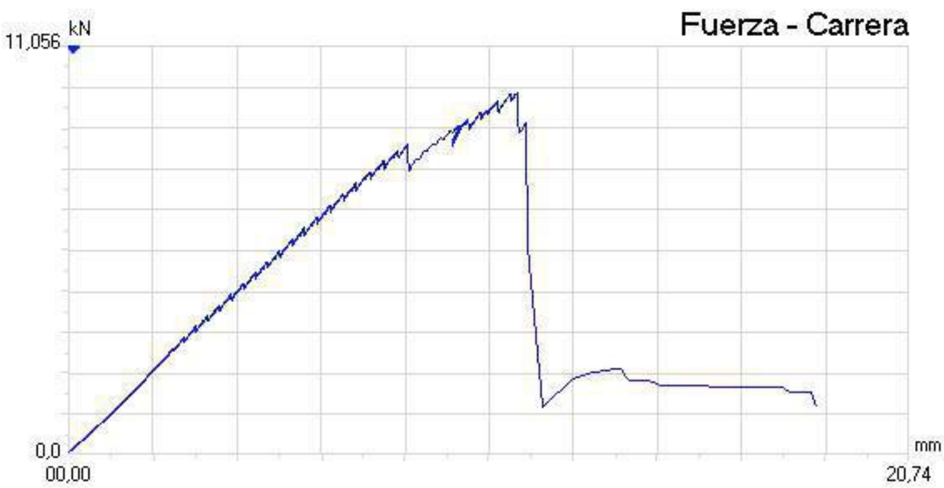
Therefore the element n.5-2, according to this rule, can not be employed for structural uses, due to the presence of the knots 6-7-8-9-10-11-12-13-14 and 26.

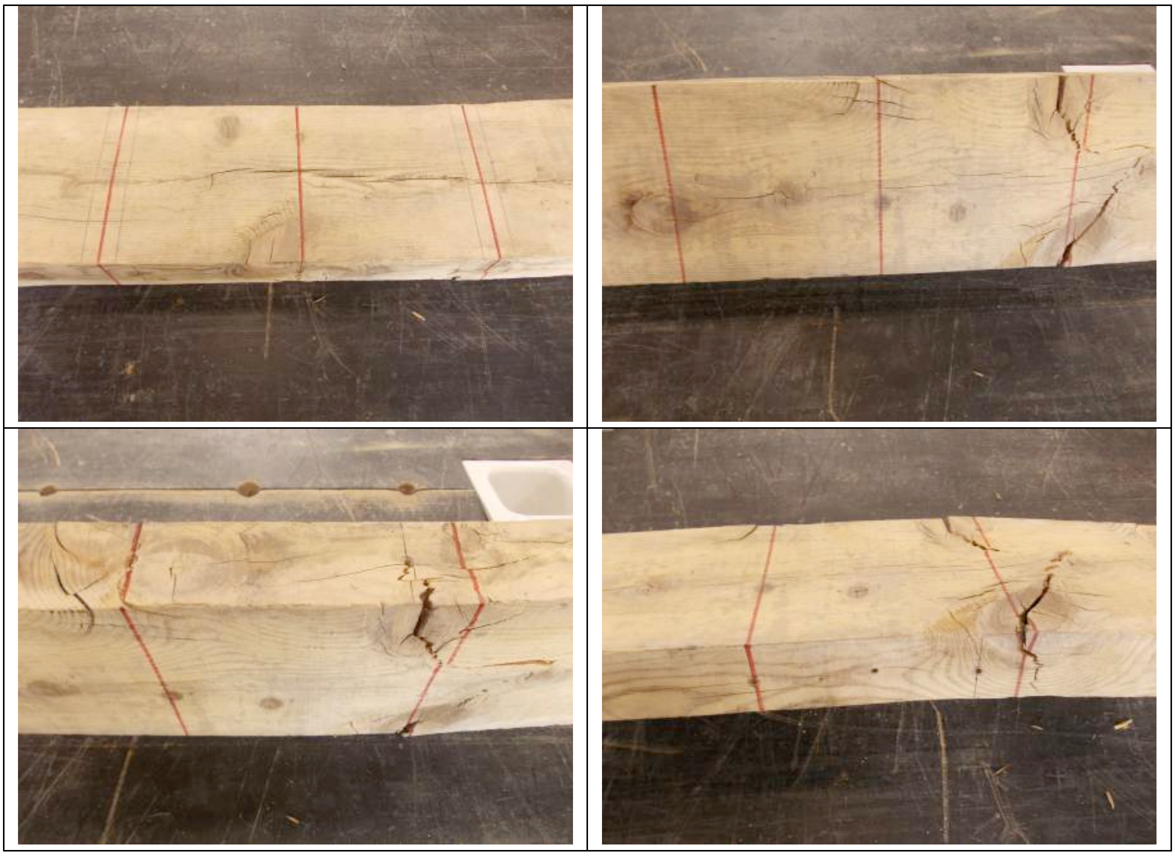
Bending strength test:

Load application side: C

The beam breaks in the area of maximum load, corresponding to the knots 10, 11 and 12. The knots 6, 7, 8, 9 although belonging to the same group of knots not have caused the break; in a similar way the knot 28, while being located in the area of maximum load in the D face, do not affect the break.

FORCE-DISPLACEMENT DIAGRAM





Code: 7

View side A-B

View side C-D

View side E

View side F

Dimensions:

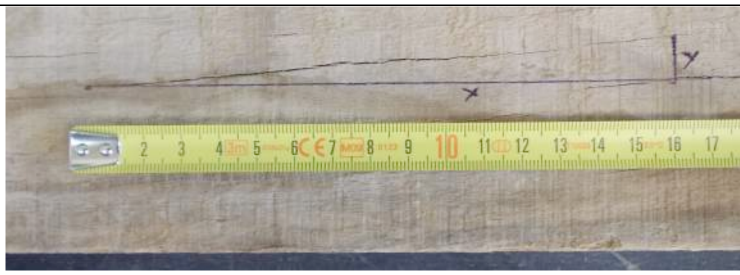
Length: 1,31 m

Section 1: 17,5 x 5,5 cm

Section 2: 17,4 x 5,8 cm

Section 3: 17,7 x 5,7 cm

Moisture:	Density:
9,90 %	537 Kg/mc
Rate of growth:	**Slope of grain:**
5,0 mm	1 cm length- 0,62 mm height

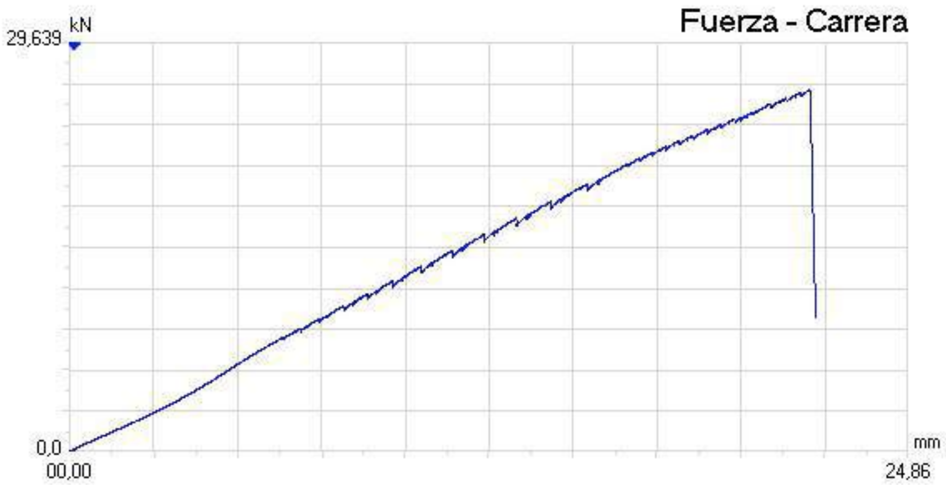


Knots: N) (x,y) d	
Where: N) reference number of knot x: x coordinate (cm) y: y coordinate (cm) d: diameter measured in a perpendicular direction to the length of the element (cm)	N) (x,y) d + ….+ N^n) (x^n, y^n) d^n = group of knots N)* = corner knot
Side A	
knots 1) (13,0 -6,5) 5,7 2) (91,3 -8,2) 3,5	*group of knots*
Side B	
knots 3)* (32,0 -5,5) 3,0	*group of knots*
Side C	
knots 4) (21,6 -8,9) 4,5 5) (97,2 -8,5) 3,7 6) 117,3 -10,0) 1,6	*group of knots*
	
Resin pocket:	
Not found	
Fissures:	
There are shrinkage cracks, mainly in the middle of the side A e slightly in the middle of the side C. There are not splits. No shake has a length greater than 1/4 of the length or than 1 meter.	

<table>
<tr><th colspan="4">Ring shakes:</th></tr>
<tr><td colspan="4">Not found</td></tr>
<tr><th colspan="4">Wane:</th></tr>
<tr><td colspan="4">Not found</td></tr>
<tr><th colspan="4">Deformations:</th></tr>
<tr><td>Bowing
Measurement with the side A upwards, right in the middle 5 mm</td><td>Crook
Not found</td><td>Twist
Measurement with the side A upwards :
Side E: 10 mm
Side F: 2 mm
Measurement with the side C upwards :
Side E: 6 mm
Side F: 9 mm</td><td>Cupping
Side A convex
Side C concave
1 mm (measurement in the side F)</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><th colspan="4">Deterioration:</th></tr>
<tr><td colspan="2">Browning of the wood due to UV short wave, evident especially in the side A, D and D. The side E presents azure blots.</td><td colspan="2"></td></tr>
<tr><th colspan="4">Other:</th></tr>
<tr><td colspan="4">There are collision cracks. In the side C there are trails of mortar. In the side C near the knot 2), it is present inclusion of cortex. In the side A there is n.1 nail having these coordinate (x,y): (120,0 – 10,0). In the side C there are n.2 holes caused by nails having these coordinates (x,y): (121,3 - 8,3); (122,0 -12,9). In the side D there are n.6 holes caused by nails having these coordinates (x,y): (17,5 – 2,8); (51,0 -0,8); (51,5 -4,4); (79,7 -2,8); (112,3 -2,0); (112,7 -4,4).</td></tr>
<tr><th colspan="4">Visual grading UNI 11035-2:</th></tr>
<tr><td colspan="4">Wanes: S1 / Knots (knot 1): S2/ Group of knots : np /Rate of growth: S1 / Slope of grain: S1 /Shakes: S1 / Deterioration: S1/ Insect attack: S1/ Deformations: S3.
Therefore the element n.7, according to this rule, has the category S3.</td></tr>
</table>

Visual grading UNE 56544:
Knots side A or C: ME-2 /knots side B or D: ME-2/ Rate of growth: ME-2 / Shrinkage cracks : ME-1/ Ring shakes: ME-1/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: ME-1/ Biological degradation:ME-1/ Deformations: ME-2 Therefore the element n.7, according to this rule, has the category ME-2.

Bending strength test:
Load application side: C The beam breaks right in the middle of area of maximum load, there are not defects (knots, wanes, etc.). The break line do not follows the slope of grain. The break is slightly affected by knot 3, that is located in the side B. FORCE-DISPLACEMENT DIAGRAM



Code: **8**

View side A-B

View side C-D

View side E

View side F

Dimensions:

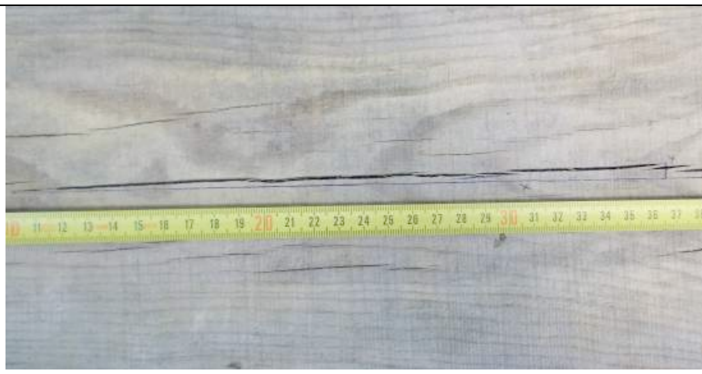
Length: 1,41 m

Section 1: 17,5 x 5,8 cm

Section 2: 17,2 x 5,8 cm

Section 3: 17,1 x 5,6 cm

Moisture:	Density:
9,50 %	585 Kg/mc
Rate of growth:	**Slope of grain:**
1,2 mm	1 cm di length- 0,22 mm height



Knots: N) (x,y) d

Where:

N) reference number of knot

x: x coordinate (cm)

y: y coordinate (cm)

d: diameter measured in a perpendicular direction to the length of the element (cm)

N) (x,y) d + ….+ N^{n}) (x^{n}, y^{n}) d^{n} = group of knots

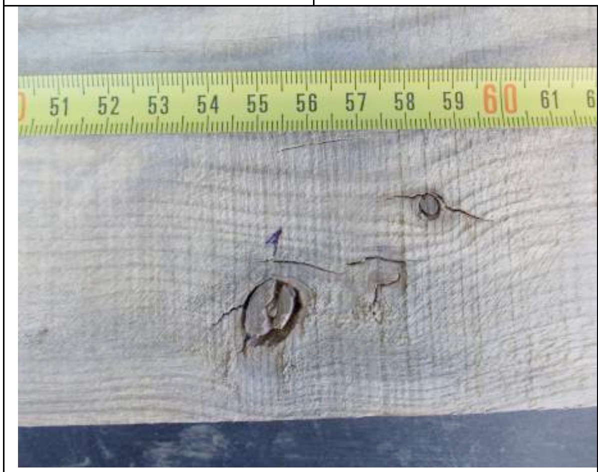
N)* = corner knot

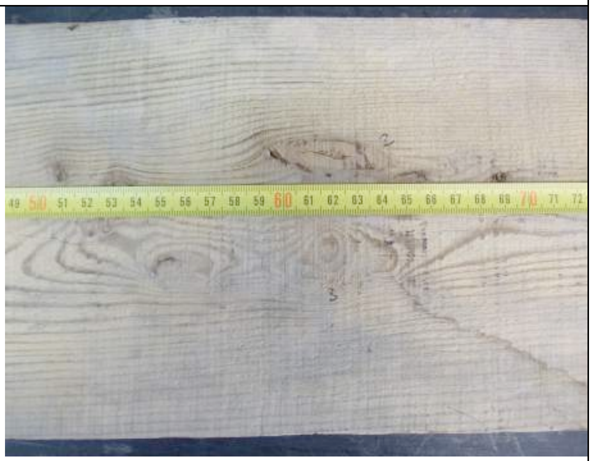
Side A

knots	*group of knots*
1) (55,3 -15,2) 1,4	

Side C

knots	*group of knots*
	2) (62,2 -6,2) 1,1 + 3) (61,7 -10,1) 1,1





Resin pocket: N (x,y) l

Where:

N: reference number of resin pocket

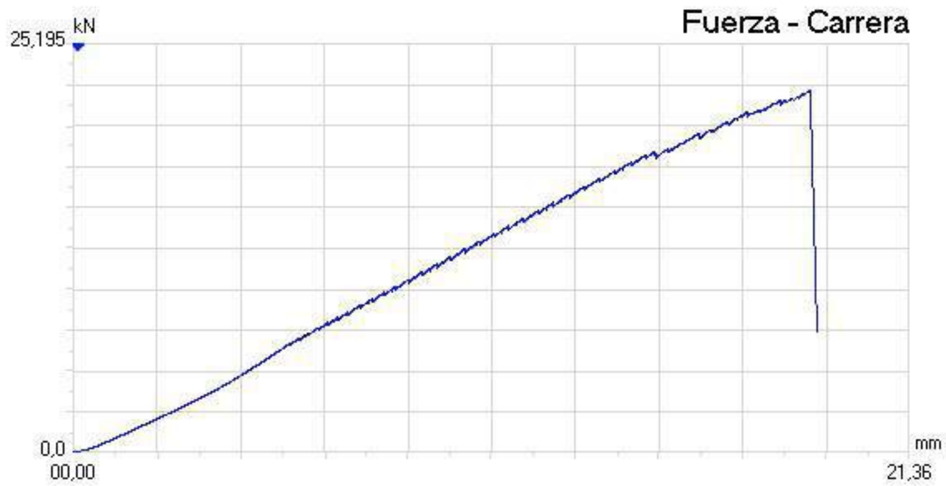
x: x coordinate x (cm)

y: y coordinate (cm)

l: diameter measured in a parallel direction to the length of the element (mm)

Side C	Side D
1 (78,0 -16,5) 19 2 (132,3 -3,6) 30	3 (128,5 -4,5) 27

<table>
<tr><th colspan="4">Fissures:</th></tr>
<tr><td colspan="2">There are shrinkage cracks, mainly in the middle of the side A. In the side B the shakes are affected by the nails.
There are not splits. No shake has a length greater than 1/4 of the length or than 1 meter.</td><td colspan="2"></td></tr>
<tr><th colspan="4">Ring shakes:</th></tr>
<tr><td colspan="4">Not found</td></tr>
<tr><th colspan="4">Wane:</th></tr>
<tr><td colspan="4">Not found</td></tr>
<tr><th colspan="4">Deformations:</th></tr>
<tr><td>Bowing
Measurement with the side C upwards right in the middle 7 mm
Measurement with the side A upwards
Extremity side E: 8 mm
Extremity side F: 4 mm</td><td>Crook
Not found</td><td>Twist
Measurement with the side A upwards
Side E: 4 mm
Side F: 6 mm</td><td>Cupping
Side A convex
Side C concave
1 mm (measurement in the side E)</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><th colspan="4">Deterioration:</th></tr>
<tr><td colspan="2">Browning of the wood due to UV short wave and blots, evident especially in the side C.</td><td colspan="2"></td></tr>
</table>

Other:
In the side E there is pith, in the side F there is double pith. The inclusion of the cortex is present in he side F, between the side F and the side A and in the side D near the resin pocket n.3. In the side B there are n.6 holes caused by nails having these coordinates (x,y): (25,5 -4,8); (26,8 -1,3); (58,5 -2,5); (89,5 -3,5); (91,0 -1,7); (120,5 -2,5). In the side D there is n.1 nail having these coordinates (x,y): (108,3 -2,5).
Visual grading UNI 11035-2:
Wanes: S1 / Knots (knot 1): S1/ Group of knots (knots 2-3): S1 /Rate of growth: S1 / Slope of grain: S1 /Shakes: S1 / Deterioration: S1/ Insect attack: S1/ Deformations: S1. Therefore the element n.8, according to this rule, has the category S1.
Visual grading UNE 56544:
Knots side A or C: ME-1 /knots side B or D: ME-1/ Rate of growth: ME-1 / Shrinkage cracks : ME-1/ Ring shakes: ME-1/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: ME-1/ Biological degradation:ME-1/ Deformations: ME-1 Therefore the element n.8, according to this rule, has the category ME-1.
Bending strength test:
Load application side: C The beam breaks in the area of maximum load, where there are not relevant defects. The break line follows the slope of grain. FORCE-DISPLACEMENT DIAGRAM


Code: 10

View side A-B

View side C-D

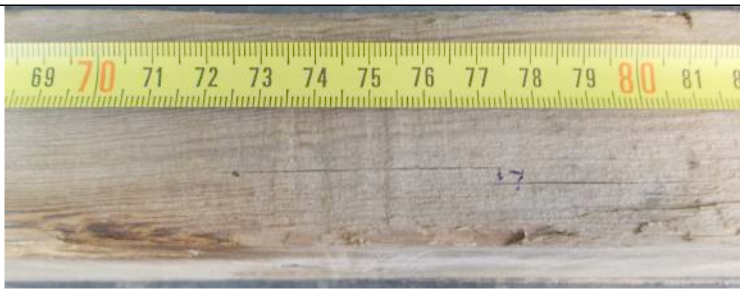
View side E

View side F

Dimensions:

Length: 1,20 m
Section 1: 14,3 x 4,5 cm
Section 2: 13,7 x 4,6 cm
Section 3: 13,7 x 4,6 cm

Moisture:	Density:
11,0 %	581 Kg/mc
Rate of growth:	**Slope of grain:**
1,0 mm	1 cm length- 0,40 mm height

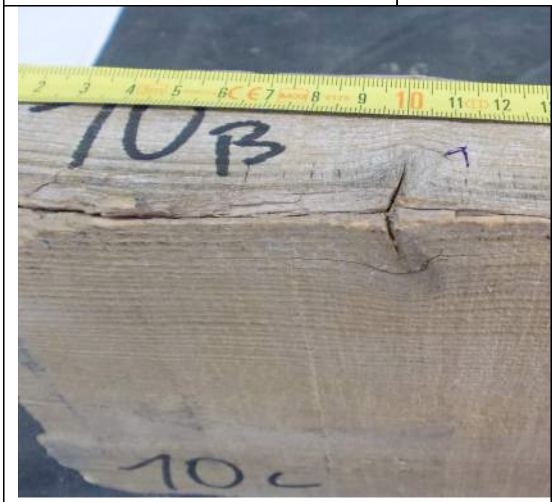


Knots: N) (x,y) d

Where:
N) reference number of knot
x: x coordinate (cm)
y: y coordinate (cm)
d: diameter measured in a perpendicular direction to the length of the element (cm)

N) (x,y) d + ….+ N^n) (x^n, y^n) d^n = group of knots
N)* = corner knot

Side B	
knots 1)* (9,8 -4,0) 1,5 2)* (25,1 -4,0) 1,3 3)* (36,3 -4,0) 1,7 4)* (52,0 -3,5) 2,8	*group of knots*



Resin pocket: N (x,y) l

Where:

N: reference number of resin pocket

x: x coordinate x (cm)

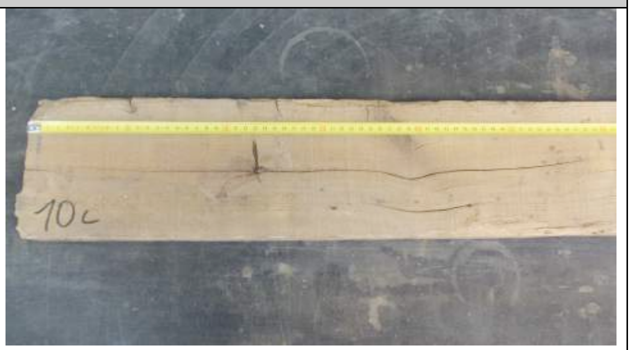
y: y coordinate (cm)

l: diameter measured in a parallel direction to the length of the element (mm)

Side B
1 (109,7 -3,7) 6

Fissures:

There are shrinkage cracks, mainly in the side F with radial direction. The side C has a relevant crack affected by a nail. The crack has a length of 45 cm, greater than 1/4 of the length.



Ring shakes:

Not found

Wane:

Not found

Deformations:

Bowing	Crook	Twist	Cupping
Not found	Measurement with the side B upwards, right in the middle 2 mm.	Not found	Side A convex Side C concave 1 mm (measurement in the side F)

Deterioration:

Browning of the wood due to UV short wave and blots, evident especially in the side A.

Other:

In the side A there are n.3 nails having these coordinates (x,y): (25,0 -7,4); (112,1 -7,7); (72,3 -6,6). The first two nails pass in the beam, in the side C the coordinates (x,y) are: (23,5 -7,5); (109,2 -6,3).

Visual grading UNI 11035-2:

Wanes: S1 / Knots (knot 3): S2/ Group of knots: np /Rate of growth: S1 / Slope of grain: S1 /Shakes: < S3 / Deterioration: S1/ Insect attack: S1/ Deformations: S1.
Therefore the element n.10, according to this rule, can not be employed for structural uses, due to the presence of the shake in the side C.

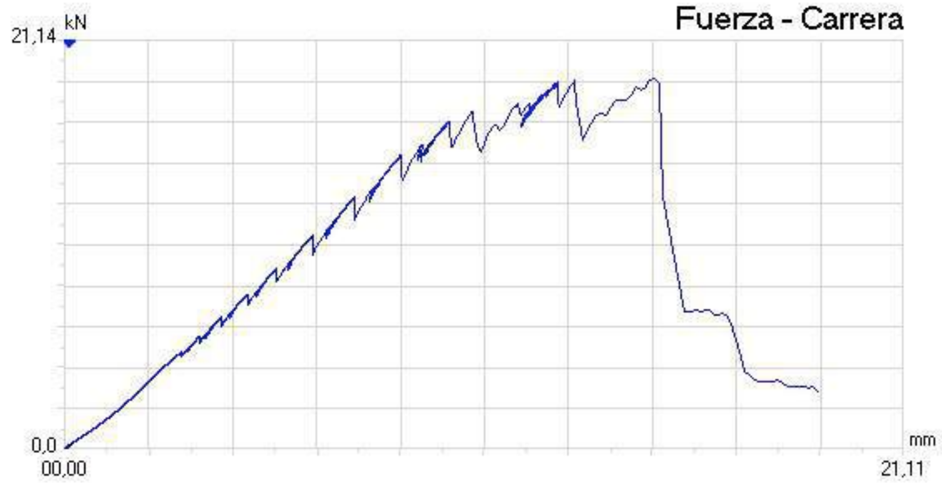
Visual grading UNE 56544:

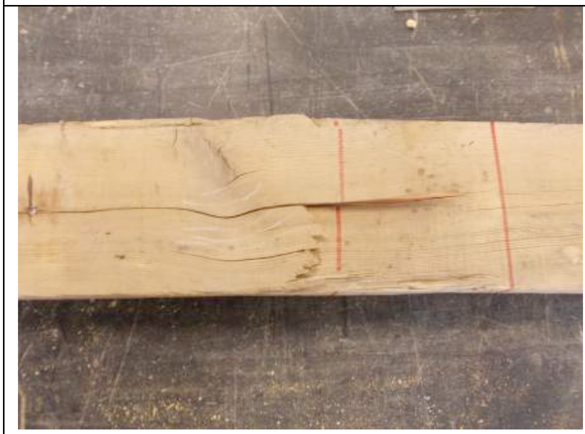
Knots side A or C: ME-1 /knots side B or D: ME-2/ Rate of growth: ME-1 / Shrinkage cracks : <ME-2/ Ring shakes: ME-1/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: ME-1/ Biological degradation:ME-1/ Deformations: ME-1
Therefore the element n.10, according to this rule, can not be employed for structural uses, due to the presence of the shake in the side C.

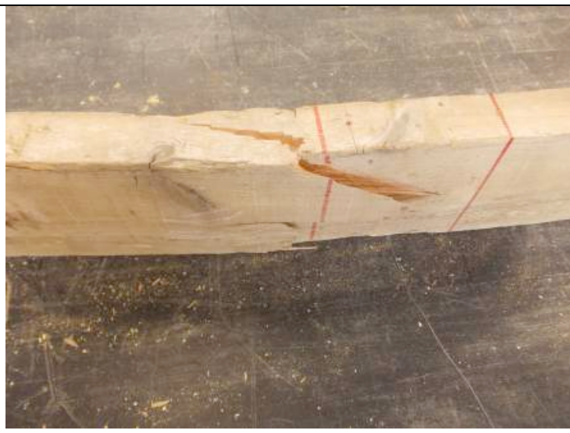
Bending strength test:

Load application side: A
The beam breaks slightly out of the area of maximum load, due to the shake in the side C (length 45 cm). The knot 4, although it is in the area of maximum load, do not affect the break. The break line follows the slope of grain.

FORCE-DISPLACEMENT DIAGRAM







Code: 11

View side A-B

View side C-D

View side E

View side F

Dimensions:

Length: 1,42 m

Section 1: 17,3 x 5,5 cm

Section 2: 17,3 x 5,6 cm

Section 3: 17,6 x 5,6 cm

Moisture:	Density:
9,50 %	548 Kg/mc
Rate of growth:	**Slope of grain:**
2,0 mm	1 cm length- 0,10 mm height

Knots: N) (x,y) d

Where:

N) reference number of knot
x: x coordinate (cm)
y: y coordinate (cm)
d: diameter measured in a perpendicular direction to the length of the element (cm)

N) (x,y) d + ….+ N^n) (x^n, y^n) d^n = group of knots
N)* = corner knot

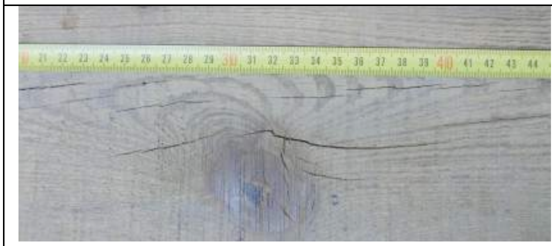
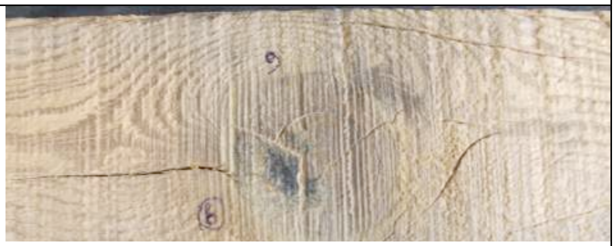
Side A	
knots	*group of knots*
1) (9,3 -15,5) 2,4 2) (32,0 -13,5) 4,0 6) (126,0 -4,3) 3,5 7) (122,3 -15,6) 2,0 8) (140,5 -4,5) 2,3	3)* (75,0 -16,8) 3,5 + 4) (86,5 -5,5) 2,2 +5) (95,5 -9) 1,7
Side B	
knots	*group of knots*
9) (110,0 -9,5) 3,8 10) (138,3 -2,7) 1,8	
Side C	
knots	*group of knots*
11) (5,8 -7,6) 1,7	
Side D	
knots	*group of knots*
12)* (10,2 -0,5) 2,7 13)* (58,7 -0,2) 2,5 14) (136,3 -1,0) 0,8	

Resin pocket: N (x,y) l

Where:

N: reference number of resin pocket
x: x coordinate x (cm)

y: y coordinate (cm)
l: diameter measured in a parallel direction to the length of the element (mm)

Side A	Side D
1 (31,5 -13,5) 6 2 (86,0 -5,5) 6 3 (95,0 -9,0) 6 4 (109,0 -0,3) 11 5 (106,5 -9,2) 4 6 (109,0 -3,5) 8	7 (8,5 -1,0) 6 8 (55,7 -0,5) 11
	

Fissures:

There are shrinkage cracks, mainly in the middle of the sides A and C, slightly in the side B and D. In the side F there is a radial crack with depth of 4,5 cm and a length of 9,5 cm, that extends in the side A.

There are not splits. No shake has a length greater than 1/4 of the length or than 1 meter.

Ring shakes:

In the side F there is a ring shake.

Wane:

Not found

Deformations:

Bowing	Crook	Twist	Cupping
Not found	Not found	Measurement with the side A upwards: Side E: 8 mm, side F: 13 mm Measurement with the side C upwards: Side E: 7 mm, side F: 14 mm	Side A convex Side C concave 1,5 mm (measurement in the side F)

Deterioration:

Browning of the wood due to UV short wave, evident in all sides, except the side E.

Other:

In the side F there is the pith, in the sides F and E it is noticeable the heartwood for its colour.
In the side A there is n.1 nail having these coordinates (x,y): (137,7 -8,5). The nail crosses the beam, in the side C has the (x,y): (137,3 -10,5).
In the side B there are n.4 holes caused by nails having these coordinates (x,y): (4,7 -3,3); (35,7 -4); (68,3 -2,4); (100,7 -2,7).

Visual grading UNI 11035-2:

Wanes: S1 / Knots (knot 12): S3/ Group of knots (knots 3-4-5): S1 /Rate of growth: S1 / Slope of grain: S1 /Shakes: S1 / Deterioration: S1/ Insect attack: S1/ Deformations: S3.
Therefore the element n.1, according to this rule, has the category S3.

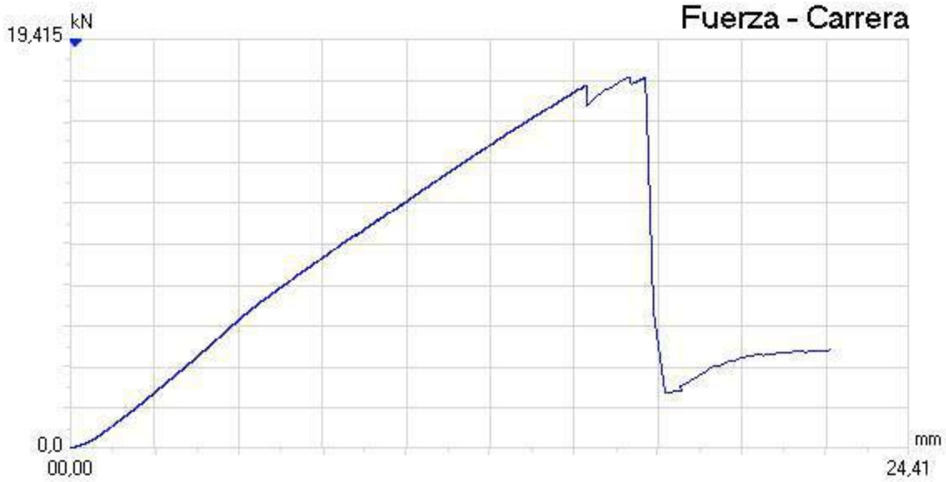
Visual grading UNE 56544:

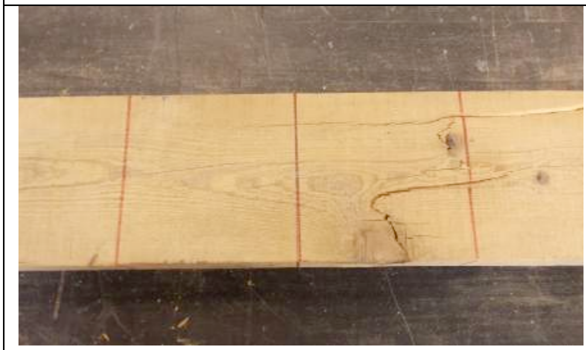
Knots side A or C: ME-2 /knots side B or D: ME-2/ Rate of growth: ME-1 / Shrinkage cracks : ME-1/ Ring shakes: <ME-2/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: ME-1/ Biological degradation:ME-1/ Deformations: ME-1
Therefore the element n.1, according to this rule, can not be employed for structural uses, due to the presence of the ring shake.

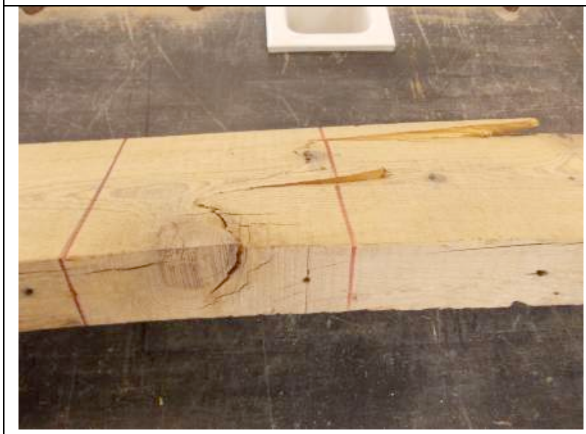
Bending strength test:

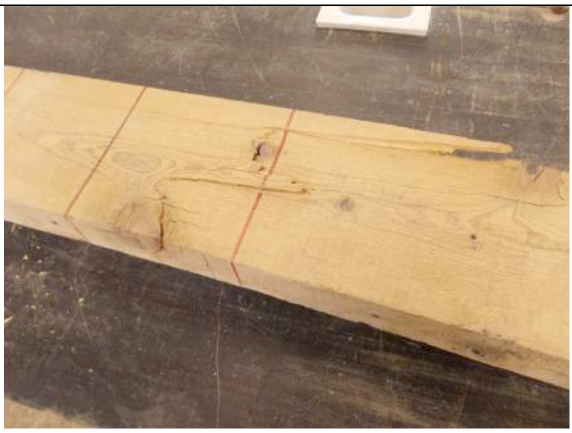
Load application side: C
The beam breaks in the area of maximum load, corresponding to the knots 4 and 5 and out of the area of maximum load in the corner between the sides A and D. The knot 13 is in the area of maximum load and it do not affect the break, because it is in the side C.

FORCE-DISPLACEMENT DIAGRAM









Code: **12**

View side A-B

View side C-D

View side E

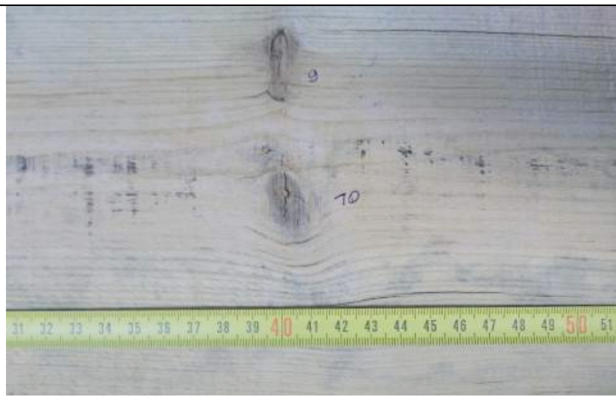
View side F

Dimensions:

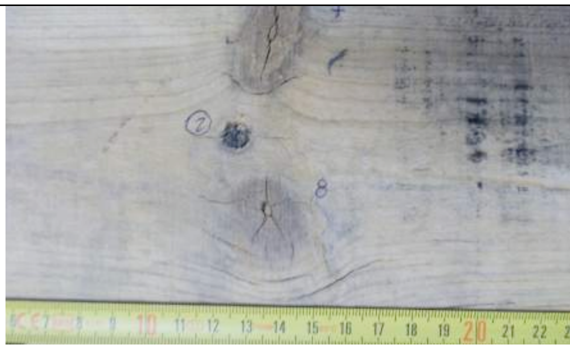
Length: 1,24 m
Section 1: 17,3 x 5,5 cm
Section 2: 17,2 x 5,7 cm
Section 3: 17,4 x 5,8 cm

Moisture:	Density:
9,4 %	498 Kg/mc
Rate of growth:	**Slope of grain:**
2,2 mm	1 cm length- 0,67 mm height

Knots: N) (x,y) d	
Where: N) reference number of knot x: x coordinate (cm) y: y coordinate (cm) d: diameter measured in a perpendicular direction to the length of the element (cm)	N) (x,y) d + ….+ N^n) (x^n, y^n) d^n = group of knots N)* = corner knot
Side A	
knots	*group of knots*
1) (17,0 -3,0) 4,6 4) (80,6 -12,0) 3,5 5) (113,0 -4,8) 4,5	2) (42,5 -2,3) 3,7 + 3) (58,4 -7,3) 4,2
Side B	
knots	*group of knots*
6) (15,1 -3,0) 1,6	
Side C	
knots	*group of knots*
11) (56,5 -7,5) 2,0 12) (79,0 -8,5) 2,7 13) (111,0 -8,5) 4,0	7) (13,7 -5,0) 3,5 + 8) (13,5 -10,5) 2,7 9) (40,2 -4,5) 3,0 + 10) (40,2 -9,5) 2,3
Side D	
knots	*group of knots*
14) (81,4 -3,5) 3,2	

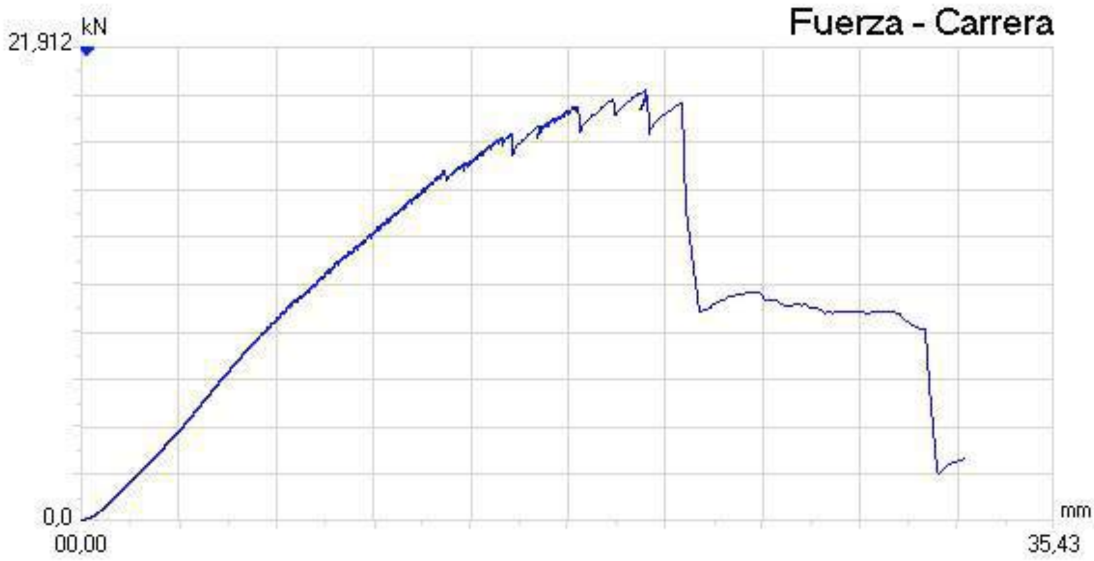


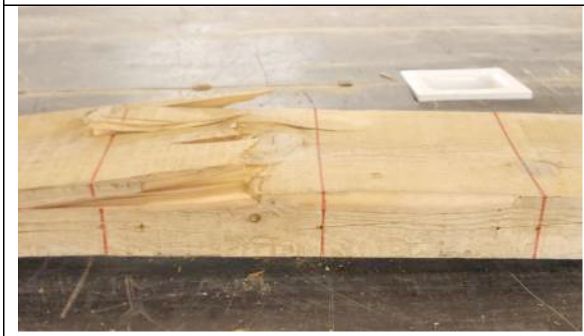
Resin pocket: N (x,y) l	
Where: N: reference number of resin pocket x: x coordinate x (cm)	y: y coordinate (cm) l: diameter measured in a parallel direction to the length of the element (mm)
Side A	**Side C**
1 (111,7 -5,0) 7	2 (12,7 -8,2) 8

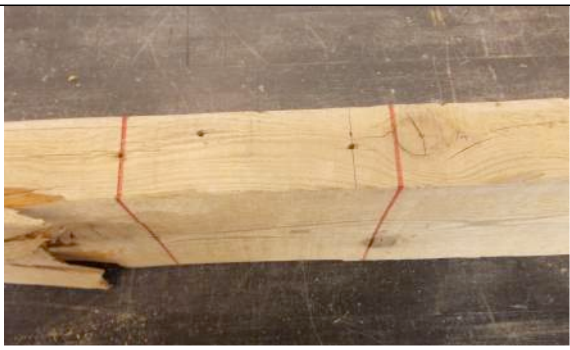
	
Fissures:	
There are shrinkage cracks, mainly in the middle of the sides a and C and slightly in the sides C and D. In the side C there is a shake, that is affected by the nail. This shake starts from the middle of the beam and arrives at the side F. Its length is 68 cm, greater than 1/4 of the length of the beam. This shake is constituted by overlapping segments (as visible in the picture). In the side F there are radial shrinkage cracks. In the side E there is only 1 shake. There are not splits.	 
Ring shakes:	
Not found	
Wanes: N^{NM}/ Pc -L ---S	
Where: N: reference number of the wane ^{AB}: borderline sides Pc: centre point calculated with respect to the reference axis y=0 (cm)	L: length of the wane (cm) S: more unfavourable ratio between the projection of the wane on a surface and the total width of the surface.
1^{AD}/ 20,0 -40,0 ---0,18	

<table>
<tr><th colspan="4">Deformations:</th></tr>
<tr>
<td>Bowing
Not found</td>
<td>Crook
Not found</td>
<td>Twist
Measurement with the side A upwards:
Side E: 6 mm
Side F: 10 mm
Measurement with the side C upwards
Side E: 4 mm
Side F: 9 mm</td>
<td>Cupping
Side A convex
Side C concave
1,0 mm (measurement in the side F)</td>
</tr>
<tr>
<td colspan="2"></td>
<td colspan="2"></td>
</tr>
<tr><th colspan="4">Deterioration:</th></tr>
<tr>
<td colspan="2">Browning of the wood due to UV short wave and blots.</td>
<td colspan="2"></td>
</tr>
<tr><th colspan="4">Other:</th></tr>
<tr><td colspan="4">In the side F there is pith and in the side E the heartwood is noticeable for its colour. In the side C there are tracks of mortar.
At the border between the side B and the side C there is a teeth having a length of 28,5 cm, height from 1.5 cm to 3 cm and depth of 0.6 cm. Between the side A and the side D, in the corner, there is a teeth having a length of 29,6 cm, with middle point in x=63,3 cm. In the side A, under the knot 3, there is a damage, formed by the compression of the fiber.
In the side A there is n.1 nail having these coordinates (x,y): (121,1 – 9,5).
In the side C there are n.2 nails having these coordinates (x,y): (122,4 -5,3); (122,0 -9,6).
In the side D there are n.7 holes caused by nails having these coordinates (x,y): (3,7 -2,0); (35,5 -5,0); (36,7 -1,7); (67,3 -1,6); (94,0 -3,5); (100,0 -1,4); (100,3 -4,6).</td></tr>
<tr><th colspan="4">Visual grading UNI 11035-2:</th></tr>
<tr><td colspan="4">Wanes: S1 / Knots (knot 14): S3/ Group of knots (knots 2-3): S1 /Rate of growth: S1 / Slope of grain: S1 /Shakes: S1 / Deterioration: S1/ Insect attack: S1/ Deformations: S3.
Therefore the element n.12, according to this rule, has the category S3.</td></tr>
</table>

Visual grading UNE 56544:
Knots side A or C: ME-2 /knots side B or D: ME-2/ Rate of growth: ME-1 / Shrinkage cracks : ME-1/ Ring shakes: ME-1/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: ME-1/ Biological degradation:ME-1/ Deformations: ME-2. Therefore the element n.12, according to this rule, present the category ME-2.
Bending strength test:
Load application side: C The beam breaks in the area of maximum load, corresponding to the knot 3 and the damage under it. The wane between the sides A and D, the knots 4 and 14, although located in the load line, do not affect the break. FORCE-DISPLACEMENT DIAGRAM







Code: 13

View side A-B

View side C-D

View side E

View side F

Dimensions:

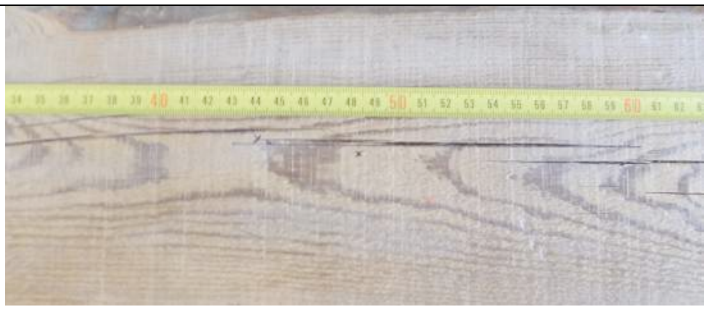
Length: 1,15 m

Section 1: 17,4 x 6,0 cm

Section 2: 17,5 x 6,0 cm

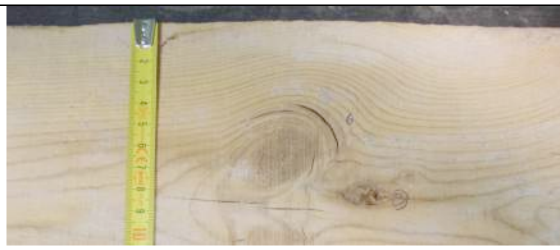
Section 3: 17,5 x 6,0 cm

Moisture:	Density:
9,4 %	463 Kg/mc
Rate of growth:	**Slope of grain:**
2,0 mm	1 cm length- 0,13 mm height



Knots: N) (x,y) d	
Where: N) reference number of knot x: x coordinate (cm) y: y coordinate (cm) d: diameter measured in a perpendicular direction to the length of the element (cm)	N) (x,y) d + ….+ N^{n}) (x^{n}, y^{n}) d^{n} = group of knots N)* = corner knot
Side A	
knots 3) (109,5 -13,5) 0,9	*group of knots* 1)* (70,8 -2,0) 3,7+ 2)* (80,0 -15,3) 5,0
Side B	
knots 4)* (93,0 -6,0) 3,3	*group of knots* 6) (76,0 -6,9) 3,0 + 7) (76,1 -11,5) 4,0 8) (106,5 -7,7) 1,7 +9)* (106,0 -16,0) 4,5
Side C	
knots 5) (31,0 -11,0) 2,8	*group of knots*
Side D	
knots 10)* (95,7 -2,2) 5,0	*group of knots*


Resin pockets: N (x,y) l	
Where: N: reference number of resin pocket x: x coordinate x (cm)	y: y coordinate (cm) l: diameter measured in a parallel direction to the length of the element (mm)
Side A	Side C
1 (77,3 -2,7) 4 2 (95,0 -11,5) 5	3 (80,0 -8,5) 17

Fissures:

There are shrinkage cracks, mainly in the middle of side A, the biggest shake has a length of 28,0 cm, it is equal to 1/4 of the length of the beam. Between the sides A and B, near the wane, there is a relevant crack, that has a length of 24,5 cm. The sides C and B have few shakes near the knots.
In the side B the direction of the shakes is affected by the presence of nails. In the side D there are n.2 shakes that have a length between 15 cm and 10 cm. In the side F there are radial cracks, the biggest has a depth of 3,5 cm. There are not splits.

Ring shakes:

Not present

Wanes: N^{NM}/ Pc -L ---S

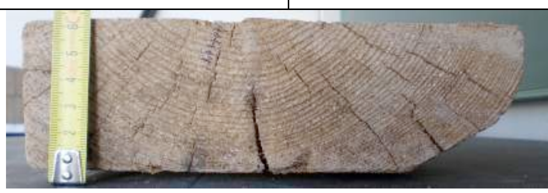
Where:
N: reference number of the wane
^{AB}: borderline sides
Pc: centre point calculated with respect to the reference axis y=0 (cm)

L: length of the wane (cm)
S: more unfavourable ratio between the projection of the wane on a surface and the total width of the surface.

1^{AB}/ 36,5 -73,0 + 2^{AD}/ 37,5 -75,0 ---0,41
3^{AB}/ 107,0 -18,0 --- 0,58

Deformations:

Bowing	Crook	Twist	Cupping
Measurement with the side C upwards: Extremity side F: 5mm	Not found	Measurement with the side A upwards: Side E: 2mm	Not found



Deterioration:

Browning of the wood due to UV short wave in all sides, except the sides E and C.

Other:

In the side C there are tracks of mortar. There are, also, many damages caused by impacts.
In the side A there is n.1 hole caused by nail having these coordinates (x,y): (113,0 -8,5). In the side C there is n.1 hole caused by nail having these coordinates (x,y): (113,5 -10). In the side B there are n. 3 holes caused by nails having these coordinates (x,y): (30,0 -4,0); (61,0 -2,7); (92,5 -2,1).

Visual grading UNI 11035-2:

Wanes: <S3 / Knots (knot 10):<S3/ Group of knots (knots 1-2): S1 /Rate of growth: S1 / Slope of grain: S1 /Shakes: S1 / Deterioration: S1/ Insect attack: S1/ Deformations: S1.
Therefore the element n.13, according to this rule, can not be employed for structural uses, due to the presence of the wanes the knot n.10.

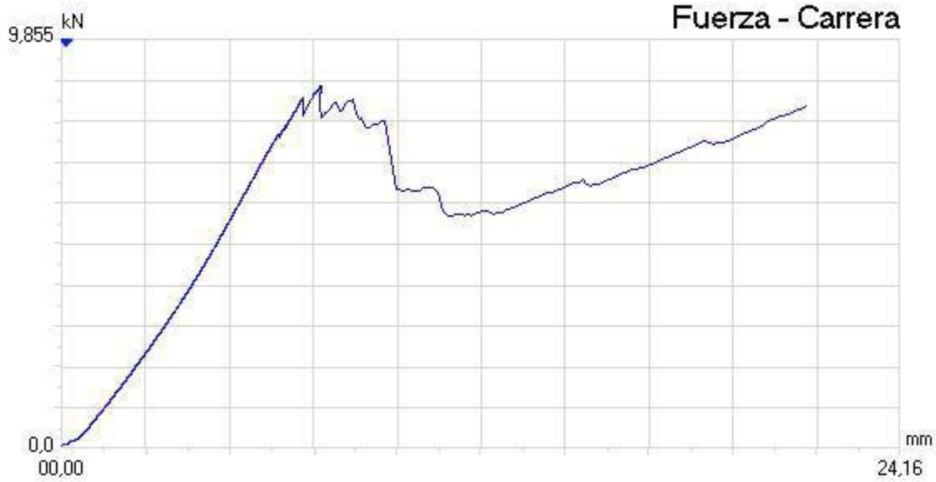
Visual grading UNE 56544:

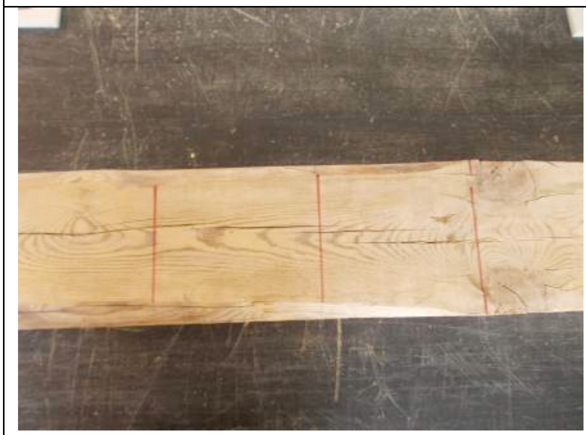
Knots side A or C: ME-2 /Knots side B or D: <ME-2 (knots 6-7)/ Rate of growth: ME-1 / Shrinkage cracks : ME-1/ Ring shakes: ME-1/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: <ME-2/ Biological degradation:ME-1/ Deformations: ME-1
Therefore the element n.13, according to this rule, can not be employed for structural uses, due to the presence of the wanes and the knots 6-7.

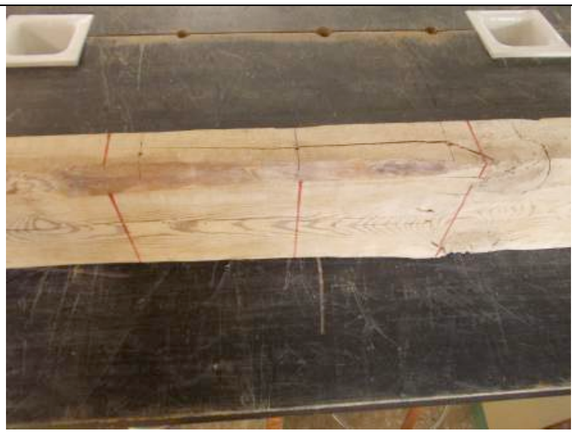
Bending strength test:

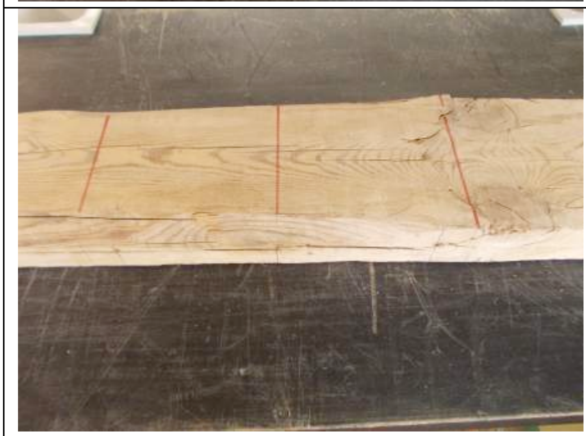
Load application side: C
The beam does not break in the area of maximum load, but at the its border; corresponding to the knots 1 and 2. The wanes, while present in the area of maximum load in the border between the sides A and B and the sides A and D, do not affect the break.

FORCE-DISPLACEMENT DIAGRAM









Code: 14

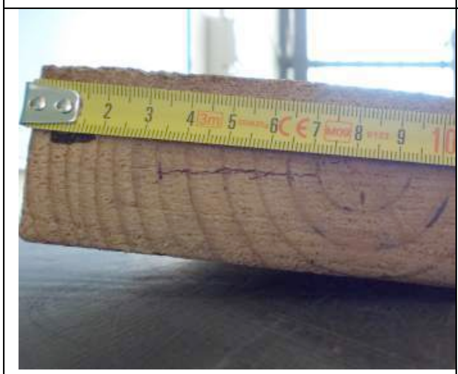
View side A-B

View side C-D

View side E

View side F

Dimensions:

Length: 1,11 m Section 1: 14,6 x 4,5 cm Section 2: 14,7 x 4,5 cm Section 3: 14,6 x 4,6 cm	
Moisture:	**Density:**
11,0 %	443 Kg/mc
Rate of growth:	**Slope of grain:**
5,0 mm	1 cm length- 0,87 mm height
	

Knots: N) (x,y) d

Where:

N) reference number of knot

x: x coordinate (cm)

y: y coordinate (cm)

d: diameter measured in a perpendicular direction to the length of the element (cm)

N) (x,y) d + ….+ N^n) (x^n, y^n) d^n = group of knots

N)* = corner knot

Side A

knots	*group of knots*
	1) (53,2 -7,5) 1,0 + 2) (53,5 -10,0) 2,0 3) (88,2 -7,4) 2,1 + 4) (88,7 -10,7) 1,2

Side B

knots	*group of knots*
5)* (51,2 -4,0) 2,0	

Side C

knots	*group of knots*
6) (52,7 -6) 1,9 7) (87,0 -12,5) 3,5	

Side D

knots	*group of knots*
8)* (49,5 -0,0) 1,6	

Resin pocket: N (x,y) l

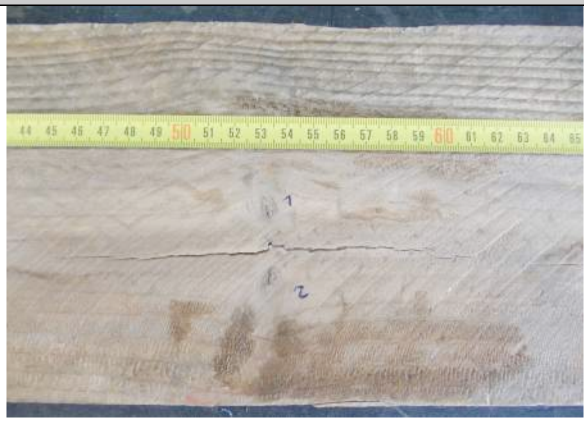
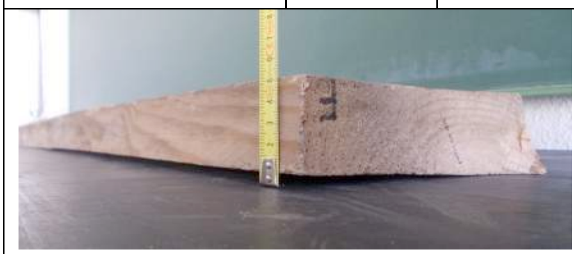
Where:

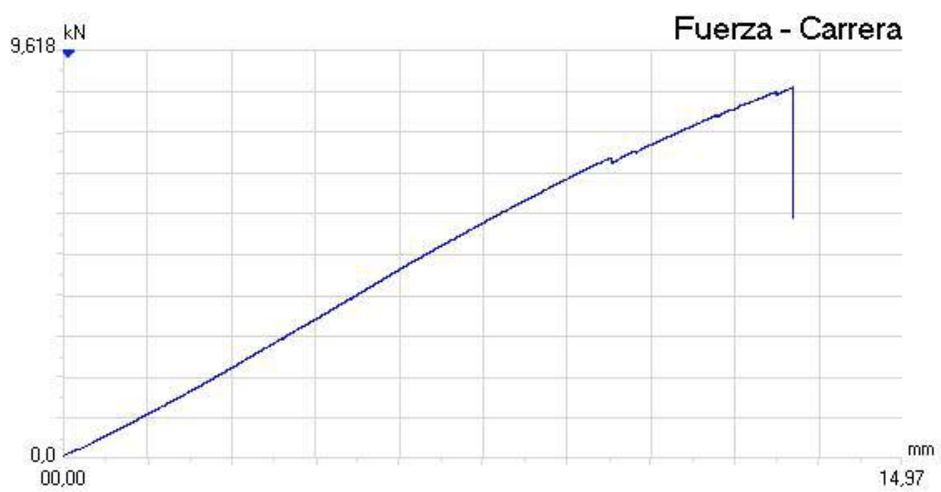
N: reference number of resin pocket

x: x coordinate x (cm)

y: y coordinate (cm)

l: diameter measured in a parallel direction to the length of the element (mm)

<table>
<tr><th colspan="4">Side C</th></tr>
<tr><td colspan="2">1 (88,6 -2,0) 16</td><td colspan="2"></td></tr>
<tr><th colspan="4">Fissures:</th></tr>
<tr><td colspan="2">There are slight shrinkage cracks only in the side A between the knots 1 and 2. There are not splits. No shake has a length greater than 1/4 of the length or than 1 meter.</td><td colspan="2"></td></tr>
<tr><th colspan="4">Ring shakes:</th></tr>
<tr><td colspan="4">Not found</td></tr>
<tr><th colspan="4">Wanes:</th></tr>
<tr><td colspan="4">Not found</td></tr>
<tr><th colspan="4">Deformations:</th></tr>
<tr><td>Bowing
Not found</td><td>Crook
Not found</td><td>Twist
Measurement with the side A upwards:
Side E: 14 mm, side F: 3 mm
Measurement with the side C upwards:
Side E: 12 mm. Side F: 6 mm</td><td>Cupping
Not Found</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><th colspan="4">Deterioration:</th></tr>
<tr><td colspan="2">Browning of the wood due to UV short wave and mildew, evident especially in the side D.</td><td colspan="2"></td></tr>
</table>

Other:
In the side E there is pith. There are slight damages caused by impacts. In the side C there are n.2 holes caused by nails having these coordinates (x,y): (96,5 -10,7); (104,5 -2,1).
Visual grading UNI 11035-2:
Wanes: S1 / Knots (knot 5):S3/ Group of knots (knots 3-4): S1 /Rate of growth: S1 / Slope of grain: S2 /Shakes: S1 / Deterioration: S1/ Insect attack: S1/ Deformations: <S3. Therefore the element n.14, according to this rule, can not be employed for structural uses, due to the presence of twist.
Visual grading UNE 56544:
Knots side A or C: ME-2 /Knots side B or D: ME-1/ Rate of growth: ME-2 / Shrinkage cracks : ME-1/ Ring shakes: ME-1/ Resin pockets: ME-1/ Slope of grain: ME-1/ Wanes: ME-1/ Biological degradation:ME-1/ Deformations: <ME-2 Therefore the element n.14, according to this rule, can not be employed for structural uses, due to the presence of twist.
Bending strength test:
Load application side: A The beam breaks in the area of maximum load, corresponding to he knots 5,6 and 8. Also the knot 6 affect the break due to its position. FORCE-DISPLACEMENT DIAGRAM


APPENDIX_ C

Characteristic values		1-1		1-2	
		UNI 11035	UNE 56544	UNI 11035	UNE 56544
Bending, N/mm^2	fm,k	22	<18	<22	<18
Tension parallel, N/mm^2	$f_{t,0,k}$	13	<11	<13	<11
Tension perpendicular, N/mm^2	$f_{t,90,k}$	0,4	<0,4	<0,4	<0,4
Compression parallel, N/mm^2	$f_{c,0,k}$	20	<18	<20	<18
Compression perpendicular, N/mm^2	$f_{c,90,k}$	3,7	<2,2	<3,7	<2,2
Shear, N/mm^2	$f_{v,k}$	3,8	<3,4	<3,8	<3,4
Mean modulus of elasticity parallel, kN/mm^2	$E_{0,mean}$	10,5	<9	<10,5	<9
5% modulus of elasticity parallel, kN/mm^2	$E_{0,05}$	7	<6	<7	<6
Mean modulus of elasticity perpendicular, kN/mm^2	$E_{90,mean}$	0,35	<0,30	<0,35	<0,30
Mean shear modulus, kN/mm^2	G_{mean}	0,66	<0,56	<0,66	<0,56
Density, kg/m^3	rk	530	<320	<530	<320
Mean density, kg/m^3	rmean	575	<380	<575	<380

red rejected value for structural use

Beam n.1

1-1	1-2
S3 (It) Rejected (Sp)	Rejected (It) Rejected (Sp)

Beam 1-1

Visual grading UNI 11035			Laboratory tests	
fm,k MPa	22	<	fm MPa	37,42
$E_{0,mean}$ KN/mm^2	10,5	>	Em,l KN/mm^2	9,41
$E_{0,05}$ KN/mm^2	7	<		
rmean kg/m^3	575	>	r kg/m^3	525
rk kg/m^3	530	>		

Beam 1-2

Visual grading UNI 11035			Laboratory tests	
fm,k MPa	<22	F	fm MPa	57,78
$E_{0,mean}$ KN/mm^2	<10,5	F	Em,l KN/mm^2	11,25
$E_{0,05}$ KN/mm^2	<7	F		
rmean kg/m^3	<575	V	r kg/m^3	534
rk kg/m^3	<530	F		

V=true
F= false

True and false are used to define the elements of which are not known characteristic values (rejected), but it is known only the maximum permissible value. "False" or ":" classification is appropriate

Em,l value and r valuewere incremented according to the humidity during the test and normalized to 12% humidity.

We consider the most unfavorable visual grading values.

Characteristic values		2-1		2-2	
		UNI 11035	UNE 56544	UNI 11035	UNE 56544
Bending, N/mm²	fm,k	<22	<18	26	18
Tension parallel, N/mm²	$f_{t,0,k}$	<13	<11	16	11
Tension perpendicular, N/mm²	$f_{t,90,k}$	<0,4	<0,4	0,4	0,4
Compression parallel, N/mm²	$f_{c,0,k}$	<20	<18	22	18
Compression perpendicular, N/mm²	$f_{c,90,k}$	<3,7	<2,2	3,7	2,2
Shear, N/mm²	$f_{v,k}$	<3,8	<3,4	4,0	3,4
Mean modulus of elasticity parallel, kN/mm²	$E_{0,mean}$	<10,5	<9	11,4	9
5% modulus of elasticity parallel, kN/mm²	$E_{0,05}$	<7	<6	7,6	6
Mean modulus of elasticity perpendicular, kN/mm²	$E_{90,mean}$	<0,35	<0,30	0,38	0,30
Mean shear modulus, kN/mm²	G_{mean}	<0,66	<0,56	0,71	0,56
Density, kg/m³	rk	<530	<320	530	320
Mean density, kg/m³	rmean	<575	<380	575	380

red rejected value for structural use

Beam n.2

2-1	2-2
Rejected (It) Rejected (Sp)	S2 ME-2

Beam 2-1					Beam 2-2				
Visual grading UNI 11035			Laboratory tests		Visual grading UNI 11035			Laboratory tests	
fm,k MPa	<22	F	fm MPa	46,66	fm,k MPa	26	<	fm MPa	37,87
$E_{0,mean}$ KN/mm²	<10,5	F	Em,l KN/mm²	14,97	$E_{0,mean}$ KN/mm²	11,4	>	Em,l KN/mm²	8,68
$E_{0,05}$ KN/mm²	<7	F			$E_{0,05}$ KN/mm²	7,6	>		
rmean kg/m³	<575	V	r kg/m³	488	rmean kg/m³	575	>	r kg/m³	536
rk kg/m³	<530	V			rk kg/m³	530	<		

V=true True and false are used to define the elements of which are not known
F= false characteristic values (rejected), but it is known only the maximum permissible value. "False" or ":" classification is appropriate

Em,l value and r valuewere incremented according to the humidity during the test and normalized to 12% humidity.

We consider the most unfavorable visual grading values.

Characteristic values		3-1		3-2	
		UNI 11035	UNE 56544	UNI 11035	UNE 56544
Bending, N/mm²	$f_{m,k}$	<22	<18	22	<18
Tension parallel, N/mm²	$f_{t,0,k}$	<13	<11	13	<11
Tension perpendicular, N/mm²	$f_{t,90,k}$	<0,4	<0,4	0,4	<0,4
Compression parallel, N/mm²	$f_{c,0,k}$	<20	<18	20	<18
Compression perpendicular, N/mm²	$f_{c,90,k}$	<3,7	<2,2	3,7	<2,2
Shear, N/mm²	$f_{v,k}$	<3,8	<3,4	3,8	<3,4
Mean modulus of elasticity parallel, kN/mm²	$E_{0,mean}$	<10,5	<9	10,5	<9
5% modulus of elasticity parallel, kN/mm²	$E_{0,05}$	<7	<6	7	<6
Mean modulus of elasticity perpendicular, kN/mm²	$E_{90,mean}$	<0,35	<0,30	0,35	<0,30
Mean shear modulus, kN/mm²	G_{mean}	<0,66	<0,56	0,66	<0,56
Density, kg/m³	rk	<530	<320	530	<320
Mean density, kg/m³	rmean	<575	<380	575	<380

red rejected value for structural use

Beam n.3

3-1	3-2
Rejected (It) Rejected (Sp)	S3 (It) Rejected (Sp)

Beam 3-1					Beam 3-2				
Visual grading UNI 11035			Laboratory tests		Visual grading UNI 11035			Laboratory tests	
fm,k MPa	<22	F	fm MPa	30,74	fm,k MPa	22	<	fm MPa	26,79
E0,mean KN/mm²	<10,5	F	Em,l KN/mm²	13,33	E0,mean KN/mm²	10,5	>	Em,l KN/mm²	9,37
E0,05 KN/mm²	<7	F			E0,05 KN/mm²	7	<		
rmean kg/m³	<575	V	r kg/m³	509	rmean kg/m³	575	>	r kg/m³	506
rk kg/m³	<530	V			rk kg/m³	530	>		

V=true
F= false

True and false are used to define the elements of which are not known characteristic values (rejected), but it is known only the maximum permissible value. "False" or ":" classification is appropriate.

Em,l value and r valuewere incremented according to the humidity during the test and normalized to 12% humidity.

We consider the most unfavorable visual grading values.

Characteristic values		4-1		4-2	
		UNI 11035	UNE 56544	UNI 11035	UNE 56544
Bending, N/mm²	$f_{m,k}$	<22	<18	<22	<18
Tension parallel, N/mm²	$f_{t,0,k}$	<13	<11	<13	<11
Tension perpendicular, N/mm²	$f_{t,90,k}$	<0,4	<0,4	<0,4	<0,4
Compression parallel, N/mm²	$f_{c,0,k}$	<20	<18	<20	<18
Compression perpendicular, N/mm²	$f_{c,90,k}$	<3,7	<2,2	<3,7	<2,2
Shear, N/mm²	$f_{v,k}$	<3,8	<3,4	<3,8	<3,4
Mean modulus of elasticity parallel, kN/mm²	$E_{0,mean}$	<10,5	<9	<10,5	<9
5% modulus of elasticity parallel, kN/mm²	$E_{0,05}$	<7	<6	<7	<6
Mean modulus of elasticity perpendicular, kN/mm²	$E_{90,mean}$	<0,35	<0,30	<0,35	<0,30
Mean shear modulus, kN/mm²	G_{mean}	<0,66	<0,56	<0,66	<0,56
Density, kg/m³	rk	<530	<320	<530	<320
Mean density, kg/m³	rmean	<575	<380	<575	<380

red rejected value for structural use

Beam n.4

4-1	4-2
Rejected (It) Rejected (Sp)	Rejected (It) Rejected (Sp)

Beam 4-1					Beam 4-2				
Visual grading UNI 11035			Laboratory tests		Visual grading UNI 11035			Laboratory tests	
fm,k MPa	<22	F	fm MPa	26,99	fm,k MPa	<22	F	fm MPa	28,79
$E_{0,mean}$ KN/mm²	<10,5	V	Em,l KN/mm²	7,69	$E_{0,mean}$ KN/mm²	<10,5	V	Em,l KN/mm²	8,56
$E_{0,05}$ KN/mm²	<7	F			$E_{0,05}$ KN/mm²	<7	F		
rmean kg/m³	<575	V	r kg/m³	533	rmean kg/m³	<575	V	r kg/m³	516
rk kg/m³	<530	F			rk kg/m³	<530	V		

V=true True and false are used to define the elements of which are not known
F= false characteristic values (rejected), but it is known only the maximum permissible value. "False" or ":" classification is appropriate.

Em,l value and r valuewere incremented according to the humidity during the test and normalized to 12% humidity.

We consider the most unfavorable visual grading values.

Characteristic values		5-1		5-2	
		UNI 11035	UNE 56544	UNI 11035	UNE 56544
Bending, N/mm²	fm,k	26	18	<22	<18
Tension parallel, N/mm²	$f_{t,0,k}$	16	11	<13	<11
Tension perpendicular, N/mm²	$f_{t,90,k}$	0,4	0,4	<0,4	<0,4
Compression parallel, N/mm²	$f_{c,0,k}$	22	18	<20	<18
Compression perpendicular, N/mm²	$f_{c,90,k}$	3,7	2,2	<3,7	<2,2
Shear, N/mm²	$f_{v,k}$	4,0	3,4	<3,8	<3,4
Mean modulus of elasticity parallel, kN/mm²	$E_{0,mean}$	11,4	9	<10,5	<9
5% modulus of elasticity parallel, kN/mm²	$E_{0,05}$	7,6	6	<7	<6
Mean modulus of elasticity perpendicular, kN/mm²	$E_{90,mean}$	0,38	0,30	<0,35	<0,30
Mean shear modulus, kN/mm²	G_{mean}	0,71	0,56	<0,66	<0,56
Density, kg/m³	rk	530	320	<530	<320
Mean density, kg/m³	rmean	575	380	<575	<380

red rejected value for structural use

Beam n.5

5-1	5-2
S2 (It) ME-2 (Sp)	Rejected (It) Rejected (Sp)

Beam 5-1					Beam 5-2				
Visual grading UNI 11035			Laboratory tests		Visual grading UNI 11035			Laboratory tests	
fm,k MPa	26	<	fm MPa	46,84	fm,k MPa	<22	V	fm MPa	16,31
$E_{0,mean}$ KN/mm²	11,4	>	Em,l KN/mm²	9,85	$E_{0,mean}$ KN/mm²	<10,5	V	Em,l KN/mm²	6,87
$E_{0,05}$ KN/mm²	7,6	<			$E_{0,05}$ KN/mm²	<7	V		
rmean kg/m³	575	>	r kg/m³	498	rmean kg/m³	<575	V	r kg/m³	481
rk kg/m³	530	>			rk kg/m³	<530	V		

V=true
F= false True and false are used to define the elements of which are not known characteristic values (rejected), but it is known only the maximum permissible value. "False" or ":" classification is appropriate

Em,l value and r valuewere incremented according to the humidity during the test and normalized to 12% humidity.

We consider the most unfavorable visual grading values.

Characteristic values		7	
		UNI 11035	UNE 56544
Bending, N/mm²	fm,k	22	18
Tension parallel, N/mm²	$f_{t,0,k}$	13	11
Tension perpendicular, N/mm²	$f_{t,90,k}$	0,4	0,4
Compression parallel, N/mm²	$f_{c,0,k}$	20	18
Compression perpendicular, N/mm²	$f_{c,90,k}$	3,7	2,2
Shear, N/mm²	$f_{v,k}$	3,8	3,4
Mean modulus of elasticity parallel, kN/mm²	$E_{0,mean}$	10,5	9
5% modulus of elasticity parallel, kN/mm²	$E_{0,05}$	7	6
Mean modulus of elasticity perpendicular, kN/mm²	$E_{90,mean}$	0,35	0,30
Mean shear modulus, kN/mm²	G_{mean}	0,66	0,56
Density, kg/m³	rk	530	320
Mean density, kg/m³	rmean	575	380

red rejected value for structural use

Beam n.7

S3 (It)
ME-2 (Sp)

Visual grading UNI 11035			Laboratory tests	
fm,k MPa	22	<	fm MPa	47,33
$E_{0,mean}$ KN/mm²	10,5	>	Em,l KN/mm²	8,92
$E_{0,05}$ KN/mm²	7	<		
rmean kg/m³	575	>	r kg/m³	537
rk kg/m³	530	<		

V=true
F= false True and false are used to define the elements of which are not known characteristic values (rejected), but it is known only the maximum permissible value. "False" or ":" classification is appropriate

Em,l value and r valuewere incremented according to the humidity during the test and normalized to 12% humidity.

We consider the most unfavorable visual grading values.

Characteristic values		8	
		UNI 11035	UNE 56544
Bending, N/mm^2	fm,k	33	27
Tension parallel, N/mm^2	$f_{t,0,k}$	20	16
Tension perpendicular, N/mm^2	$f_{t,90,k}$	0,4	0,4
Compression parallel, N/mm^2	$f_{c,0,k}$	24	22
Compression perpendicular, N/mm^2	$f_{c,90,k}$	3,7	2,6
Shear, N/mm^2	$f_{v,k}$	4,0	4,0
Mean modulus of elasticity parallel, kN/mm^2	$E_{0,mean}$	12,3	11,5
5% modulus of elasticity parallel, kN/mm^2	$E_{0,05}$	8,2	7,7
Mean modulus of elasticity perpendicular, kN/mm^2	$E_{90,mean}$	0,41	0,38
Mean shear modulus, kN/mm^2	G_{mean}	0,77	0,72
Density, kg/m^3	rk	530	370
Mean density, kg/m^3	rmean	575	450

red rejected value for structural use

Beam n.8

S1 (It)
ME-1 (Sp)

Visual grading UNI 11035			Laboratory tests	
fm,k MPa	33	<	fm MPa	38,22
$E_{0,mean}$ KN/mm^2	12,3	>	Em,l KN/mm^2	8,71
$E_{0,05}$ KN/mm^2	8,2	<		
rmean kg/m^3	575	<	r kg/m^3	585
rk kg/m^3	530	<		

V=true
F=false True and false are used to define the elements of which are not known characteristic values (rejected), but it is known only the maximum permissible value. "False" or ":" classification is appropriate.

Em,l value and r valuewere incremented according to the humidity during the test and normalized to 12% humidity.

We consider the most unfavorable visual grading values.

Characteristic values		10	
		UNI 11035	UNE 56544
Bending, N/mm²	$f_{m,k}$	<22	<18
Tension parallel, N/mm²	$f_{t,0,k}$	<13	<11
Tension perpendicular, N/mm²	$f_{t,90,k}$	<0,4	<0,4
Compression parallel, N/mm²	$f_{c,0,k}$	<20	<18
Compression perpendicular, N/mm²	$f_{c,90,k}$	<3,7	<2,2
Shear, N/mm²	$f_{v,k}$	<3,8	<3,4
Mean modulus of elasticity parallel, kN/mm²	$E_{0,mean}$	<10,5	<9
5% modulus of elasticity parallel, kN/mm²	$E_{0,05}$	<7,0	<6
Mean modulus of elasticity perpendicular, kN/mm²	$E_{90,mean}$	<0,35	<0,30
Mean shear modulus, kN/mm²	G_{mean}	<0,66	<0,56
Density, kg/m³	rk	<530	<320
Mean density, kg/m³	rmean	<575	<380

red rejected value for structural use

Beam n.10

Rejected (It)
Rejected (Sp)

Visual grading UNI 11035			Laboratory tests	
fm,k MPa	<22	F	fm MPa	56,11
E0,mean KN/mm²	<10,5	F	Em,l KN/mm²	18,67
E0,05 KN/mm²	<7,0	F		
rmean kg/m³	<575	F	r kg/m³	581
rk kg/m³	<530	F		

V=true
F=false True and false are used to define the elements of which are not known characteristic values (rejected), but it is known only the maximum permissible value. "False" or ":" classification is appropriate

Em,l value and r valuewere incremented according to the humidity during the test and normalized to 12% humidity.

We consider the most unfavorable visual grading values.

Characteristic values		11	
		UNI 11035	UNE 56544
Bending, N/mm^2	fm,k	22	<18
Tension parallel, N/mm^2	$f_{t,0,k}$	13	<11
Tension perpendicular, N/mm^2	$f_{t,90,k}$	0,4	<0,4
Compression parallel, N/mm^2	$f_{c,0,k}$	20	<18
Compression perpendicular, N/mm^2	$f_{c,90,k}$	3,7	<2,2
Shear, N/mm^2	$f_{v,k}$	3,8	<3,4
Mean modulus of elasticity parallel, kN/mm^2	$E_{0,mean}$	10,5	<9
5% modulus of elasticity parallel, kN/mm^2	$E_{0,05}$	7,0	<6
Mean modulus of elasticity perpendicular, kN/mm^2	$E_{90,mean}$	0,35	<0,30
Mean shear modulus, kN/mm^2	G_{mean}	0,66	<0,56
Density, kg/m^3	rk	530	<320
Mean density, kg/m^3	rmean	575	<380

red rejected value for structural use

Beam n.11

S3 (It)
Rejected (Sp)

Visual grading UNI 11035			Laboratory tests	
fm,k MPa	22	<	fm MPa	31,85
E0,mean KN/mm^2	10,5	>	Em,l KN/mm^2	7,56
E0,05 KN/mm^2	7,0	<		
rmean kg/m^3	575	>	r kg/m^3	548
rk kg/m^3	530	<		

V=true
F=false
True and false are used to define the elements of which are not known characteristic values (rejected), but it is known only the maximum permissible value. "False" or ":" classification is appropriate

Em,l value and r valuewere incremented according to the humidity during the test and normalized to 12% humidity.

We consider the most unfavorable visual grading values.

Characteristic values		12	
		UNI 11035	UNE 56544
Bending, N/mm²	$f_{m,k}$	22	18
Tension parallel, N/mm²	$f_{t,0,k}$	13	11
Tension perpendicular, N/mm²	$f_{t,90,k}$	0,4	0,4
Compression parallel, N/mm²	$f_{c,0,k}$	20	18
Compression perpendicular, N/mm²	$f_{c,90,k}$	3,7	2,2
Shear, N/mm²	$f_{v,k}$	3,8	3,4
Mean modulus of elasticity parallel, kN/mm²	$E_{0,mean}$	10,5	9
5% modulus of elasticity parallel, kN/mm²	$E_{0,05}$	7,0	6
Mean modulus of elasticity perpendicular, kN/mm²	$E_{90,mean}$	0,35	0,30
Mean shear modulus, kN/mm²	G_{mean}	0,66	0,56
Density, kg/m³	rk	530	320
Mean density, kg/m³	rmean	575	380

red rejected value for structural use

Beam n.12

S3 (It)
ME-2 (Sp)

Visual grading UNI 11035			Laboratory tests	
fm,k MPa	22	<	fm MPa	35,33
$E_{0,mean}$ KN/mm²	10,5	<	Em,l KN/mm²	10,78
$E_{0,05}$ KN/mm²	7,0	<		
rmean kg/m³	575	>	r kg/m³	498
rk kg/m³	530	>		

V=true
F=false True and false are used to define the elements of which are not known characteristic values (rejected), but it is known only the maximum permissible value. "False" or ":" classification is appropriate

Em,l value and r valuewere incremented according to the humidity during the test and normalized to 12% humidity.

We consider the most unfavorable visual grading values.

Characteristic values		13	
		UNI 11035	UNE 56544
Bending, N/mm²	$f_{m,k}$	<22	<18
Tension parallel, N/mm²	$f_{t,0,k}$	<13	<11
Tension perpendicular, N/mm²	$f_{t,90,k}$	<0,4	<0,4
Compression parallel, N/mm²	$f_{c,0,k}$	<20	<18
Compression perpendicular, N/mm²	$f_{c,90,k}$	<3,7	<2,2
Shear, N/mm²	$f_{v,k}$	<3,8	<3,4
Mean modulus of elasticity parallel, kN/mm²	$E_{0,mean}$	<10,5	<9
5% modulus of elasticity parallel, kN/mm²	$E_{0,05}$	<7,0	<6
Mean modulus of elasticity perpendicular, kN/mm²	$E_{90,mean}$	<0,35	<0,30
Mean shear modulus, kN/mm²	G_{mean}	<0,66	<0,56
Density, kg/m³	rk	<530	<320
Mean density, kg/m³	rmean	<575	<380

red rejected value for structural use

Beam n.13

Rejected (It)
Rejected (Sp)

Visual grading UNI 11035			Laboratory tests	
fm,k MPa	<22	V	fm MPa	14,95
E0,mean KN/mm²	<10,5	F	Em,l KN/mm²	10,77
E0,05 KN/mm²	<7,0	V		
rmean kg/m³	<575	V	r kg/m³	463
rk kg/m³	<530	V		

V=true **F=false** True and false are used to define the elements of which are not known characteristic values (rejected), but it is known only the maximum permissible value. "False" or ":" classification is appropriate

Em,l value and r valuewere incremented according to the humidity during the test and normalized to 12% humidity.

We consider the most unfavorable visual grading values.

Characteristic values		14	
		UNI 11035	UNE 56544
Bending, N/mm²	$f_{m,k}$	<22	<18
Tension parallel, N/mm²	$f_{t,0,k}$	<13	<11
Tension perpendicular, N/mm²	$f_{t,90,k}$	<0,4	<0,4
Compression parallel, N/mm²	$f_{c,0,k}$	<20	<18
Compression perpendicular, N/mm²	$f_{c,90,k}$	<3,7	<2,2
Shear, N/mm²	$f_{v,k}$	<3,8	<3,4
Mean modulus of elasticity parallel, kN/mm²	$E_{0,mean}$	<10,5	<9
5% modulus of elasticity parallel, kN/mm²	$E_{0,05}$	<7,0	<6
Mean modulus of elasticity perpendicular, kN/mm²	$E_{90,mean}$	<0,35	<0,30
Mean shear modulus, kN/mm²	G_{mean}	<0,66	<0,56
Density, kg/m³	rk	<530	<320
Mean density, kg/m³	rmean	<575	<380

red rejected value for structural use

Beam n.14

Rejected (It)
Rejected (Sp)

Visual grading UNI 11035			Laboratory tests	
fm,k MPa	<22	F	fm MPa	23,79
E0,mean KN/mm²	<10,5	V	Em,l KN/mm²	5,54
E0,05 KN/mm²	<7,0	V		
rmean kg/m³	575	V	r kg/m³	443
rk kg/m³	530	V		

V=true
F= false True and false are used to define the elements of which are not known characteristic values (rejected), but it is known only the maximum permissible value. "False" or ":" classification is appropriate

Em,l value and r valuewere incremented according to the humidity during the test and normalized to 12% humidity.

We consider the most unfavorable visual grading values.

APPENDIX_ D

CV_1

Total impact per phase (in kg CO2-eq):

Life cycle:	21
Production:	19
Use:	2,7
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	19
Wooden boards out	0,5	p	1	14
Sawn timber, softwood	0,3	m3	0,5	13
Preservative treatment, sawn timber	0,3	m3	0,5	1
Screw+rod	1	p	1	4,8
Steel, converter, unalloyed	2,28	kg	1	3,7
Section bar rolling, steel	2,28	kg	1	0,38
Zinc coating, pieces	113040	mm2	1	0,71

Use	Amount	Unit	Number	Impact
Product	1	p	1	2,7
Transport, lorry 16-32t, EURO5	16728	kgkm	1	2,6
Drill boards	1	p	1	0,099
Electricity, Italy	0,154	kWh	1	0,099
Screw boards	1	p	1	0,071
Electricity, Italy	0,11	kWh	1	0,071

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Wooden boards out	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Screw+rod	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0

CV_1A

Total impact per phase (in kg CO2-eq):

Life cycle:	29
Production:	26
Use:	3,1
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	26
Wooden boards out	0,5	p	1	14
Sawn timber, softwood	0,3	m3	0,5	13
Preservative treatment, sawn timber	0,3	m3	0,5	1
Screw+rod	1	p	1	5,6
Steel, converter, unalloyed	2,634	kg	1	4,3
Section bar rolling, steel	2,634	kg	1	0,44
Zinc coating, pieces	143184	mm2	1	0,89
Wool insulation	1	p	1	4,8
Transport, lorry 16-32t, EURO5	150	kgkm	1	0,023
Electricity, Italy	7,41	kWh	1	4,8
Tap water	117,9	kg	1	0
Timber frame	0,5	p	1	0,26
Sawn timber, softwood	0,005	m3	0,5	0,21
Preservative treatment, sawn timber	0,005	m3	0,5	0,017
Electricity, Italy	0,09	kWh	0,5	0,029
Wooden boards in	0,5	p	1	1,2
Sawn timber, softwood	0,025	m3	0,5	1,1
Preservative treatment, sawn timber	0,025	m3	0,5	0,085

Use	Amount	Unit	Number	Impact
Product	1	p	1	3,1
Transport, lorry 16-32t, EURO5	18713,47	kgkm	1	2,9
Drill boards	1	p	1	0,099
Electricity, Italy	0,154	kWh	1	0,099
Screw boards/frame	1	p	1	0,17
Electricity, Italy	0,26	kWh	1	0,17

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Wooden boards out	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Screw+rod	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wool insulation	70 %	0 %	30 %	0
Tap water				0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Wooden boards in	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0

CV_1B

Total impact per phase (in kg CO2-eq):

Life cycle:	112
Production:	109
Use:	3,1
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	109
Wooden boards out	0,5	p	1	14
Sawn timber, softwood	0,3	m3	0,5	13
Preservative treatment, sawn timber	0,3	m3	0,5	1
Screw+rod	1	p	1	5
Steel, converter, unalloyed	2,391	kg	1	3,9
Section bar rolling, steel	2,391	kg	1	0,4
Zinc coating, pieces	114924	mm2	1	0,72
Wooden boards in	0,5	p	1	0,58
Sawn timber, softwood	0,0125	m3	0,5	0,53
Preservative treatment, sawn timber	0,0125	m3	0,5	0,043
Polycarbonate	1	p	1	89
Polycarbonate	11,5	kg	1	89

Use	Amount	Unit	Number	Impact
Product	1	p	1	3,1
Transport, lorry 16-32t, EURO5	18576,6	kgkm	1	2,9
Drill boards	1	p	1	0,099
Electricity, Italy	0,154	kWh	1	0,099
Screw boards/polycar	1	p	1	0,12
Electricity, Italy	0,185	kWh	1	0,12

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Wooden boards out	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Screw+rod	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards in	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Polycarbonate	100 %	0 %	0 %	0
Polycarbonate	100 %	0 %	0 %	0

CV_2

Total impact per phase (in kg CO2-eq):

Life cycle:	86
Production:	84
Use:	2,1
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	84
Screw+bolt	1	p	1	0,38
Steel, converter, unalloyed	0,16	kg	1	0,26
Section bar rolling, steel	0,16	kg	1	0,027
Zinc coating, pieces	14858,5	mm2	1	0,093
Wooden boards 120x25	0,5	p	1	2,3
Sawn timber, softwood	0,05	m3	0,5	2,1
Preservative treatment, sawn timber	0,05	m3	0,5	0,17
Multicom	0,5	p	1	81
Steel, low-alloyed	91,2	kg	0,5	80
Zinc coating, pieces	306460	mm2	0,5	0,96
Timber frame	0,5	p	1	0,29
Sawn timber, softwood	0,005	m3	0,5	0,21
Preservative treatment, sawn timber	0,005	m3	0,5	0,017
Electricity, Italy	0,18	kWh	0,5	0,058

Use	Amount	Unit	Number	Impact
Product	1	p	1	2,1
Transport, lorry 16-32t, EURO5	12161	kgkm	1	1,9
Screw boards/frame	1	p	1	0,23
Electricity, Italy	0,366	kWh	1	0,23

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Multicom	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0

CV_2A

Total impact per phase (in kg CO2-eq):

Life cycle:	91
Production:	89
Use:	2,2
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	89
Screw+bolt	1	p	1	0,39
Steel, converter, unalloyed	0,166	kg	1	0,27
Section bar rolling, steel	0,166	kg	1	0,028
Zinc coating, pieces	15486,5	mm2	1	0,097
Wooden boards 120x25	0,5	p	1	2,3
Sawn timber, softwood	0,05	m3	0,5	2,1
Preservative treatment, sawn timber	0,05	m3	0,5	0,17
Multicom	0,5	p	1	81
Steel, low-alloyed	91,2	kg	0,5	80
Zinc coating, pieces	306460	mm2	0,5	0,96
Timber frame	0,5	p	1	0,4
Sawn timber, softwood	0,0067	m3	0,5	0,29
Preservative treatment, sawn timber	0,0067	m3	0,5	0,023
Electricity, Italy	0,27	kWh	0,5	0,087
Wool insulation	1	p	1	4,8
Electricity, Italy	7,41	kWh	1	4,8
Tap water	117,9	kg	1	0

Use	Amount	Unit	Number	Impact
Product	1	p	1	2,2
Transport, lorry 16-32t, EURO5	12555	kgkm	1	1,9
Screw boards/frame	1	p	1	0,26
Electricity, Italy	0,403	kWh	1	0,26

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Multicom	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Wool insulation	70 %	0 %	30 %	0
Tap water				0

CV_3

Total impact per phase (in kg CO2-eq):

Life cycle:	38
Production:	37
Use:	1,1
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	37
Screw+bolt	1	p	1	0,38
Steel, converter, unalloyed	0,16	kg	1	0,26
Section bar rolling, steel	0,16	kg	1	0,027
Zinc coating, pieces	14858,5	mm2	1	0,093
Wooden boards 120x25	0,5	p	1	2,3
Sawn timber, softwood	0,05	m3	0,5	2,1
Preservative treatment, sawn timber	0,05	m3	0,5	0,17
Tubolar scaffolding	0,5	p	1	16
Steel, low-alloyed	15,152	kg	0,5	13
Zinc coating, pieces	942000	mm2	0,5	2,9
Timber frame	0,5	p	1	0,4
Sawn timber, softwood	0,0075	m3	0,5	0,32
Preservative treatment, sawn timber	0,0075	m3	0,5	0,026
Electricity, Italy	0,18	kWh	0,5	0,058
Scaffolding joints	0,5	p	1	18
Steel, converter, low-alloyed	10,36	kg	0,5	11
Hot impact extrusion, steel	10,36	kg	0,5	5,3
Zinc coating, pieces	527520	mm2	0,5	1,6

Use	Amount	Unit	Number	Impact
Product	1	p	1	1,1
Transport, lorry 16-32t, EURO5	5729,7	kgkm	1	0,88
Screw boards/frame	1	p	1	0,23
Electricity, Italy	0,366	kWh	1	0,23

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Tubolar scaffolding	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Scaffolding joints	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0

CV_3A

Total impact per phase (in kg CO2-eq):

Life cycle:	43
Production:	42
Use:	1,2
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	42
Screw+bolt	1	p	1	0,48
Steel, converter, unalloyed	0,207	kg	1	0,34
Section bar rolling, steel	0,207	kg	1	0,035
Zinc coating, pieces	17872,9	mm2	1	0,11
Wooden boards 120x25	0,5	p	1	2,3
Sawn timber, softwood	0,05	m3	0,5	2,1
Preservative treatment, sawn timber	0,05	m3	0,5	0,17
Tubolar scaffolding	0,5	p	1	16
Steel, low-alloyed	15,152	kg	0,5	13
Zinc coating, pieces	942000	mm2	0,5	2,9
Timber frame	0,5	p	1	0,55
Sawn timber, softwood	0,01	m3	0,5	0,43
Preservative treatment, sawn timber	0,01	m3	0,5	0,034
Electricity, Italy	0,27	kWh	0,5	0,087
Scaffolding joints	0,5	p	1	18
Steel, converter, low-alloyed	10,36	kg	0,5	11
Hot impact extrusion, steel	10,36	kg	0,5	5,3
Zinc coating, pieces	527520	mm2	0,5	1,6
Wool insulation	1	p	1	4,8
Electricity, Italy	7,41	kWh	1	4,8
Tap water	117,9	kg	1	0

Use	Amount	Unit	Number	Impact
Product	1	p	1	1,2
Transport, lorry 16-32t, EURO5	6171,9	kgkm	1	0,95
Screw boards/frame	1	p	1	0,26
Electricity, Italy	0,403	kWh	1	0,26

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Tubolar scaffolding	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Scaffolding joints	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Wool insulation	70 %	0 %	30 %	0
Tap water				

CV_4

Total impact per phase (in kg CO2-eq):

Life cycle:	32
Production:	30
Use:	1,2
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	30
Screw+bolt	1	p	1	0,52
Steel, converter, unalloyed	0,214	kg	1	0,35
Section bar rolling, steel	0,214	kg	1	0,036
Zinc coating, pieces	21766,48	mm2	1	0,14
Wooden board	0,5	p	1	0,37
Sawn timber, softwood	0,006	m3	0,5	0,26
Preservative treatment, sawn timber	0,006	m3	0,5	0,02
Electricity, Italy	0,3	kWh	0,5	0,096
Wooden boards 120x25	0,5	p	1	2,3
Sawn timber, softwood	0,05	m3	0,5	2,1
Preservative treatment, sawn timber	0,05	m3	0,5	0,17
UPN 180	0,5	p	1	24
Steel, converter, low-alloyed	18,888	kg	0,5	20
Hot rolling, steel	18,888	kg	0,5	2,6
Zinc coating, pieces	0,5817	m2	0,5	1,8
Steel Bracket	1	p	1	2,9
Steel, converter, low-alloyed	0,9444	kg	1	2
Hot rolling, steel	0,9444	kg	1	0,26
Zinc coating, pieces	0,097	m2	1	0,61

Use	Amount	Unit	Number	Impact
Product	1	p	1	1,2
Transport, lorry 16-32t, EURO5	5085,64	kgkm	1	0,78
Screw boards	1	p	1	0,41
Electricity, Italy	0,635	kWh	1	0,41

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden board	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
UPN 180	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Steel Bracket	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0

CV_4A

Total impact per phase (in kg CO2-eq):

Life cycle:	53
Production:	52
Use:	1,6
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	52
Screw+bolt	1	p	1	0,64
Steel, converter, unalloyed	0,263	kg	1	0,43
Section bar rolling, steel	0,263	kg	1	0,044
Zinc coating, pieces	26790,48	mm2	1	0,17
Wooden board	0,5	p	1	0,51
Sawn timber, softwood	0,009	m3	0,5	0,39
Preservative treatment, sawn timber	0,009	m3	0,5	0,031
Electricity, Italy	0,3	kWh	0,5	0,096
Wooden boards 120x25	0,5	p	1	2,3
Sawn timber, softwood	0,05	m3	0,5	2,1
Preservative treatment, sawn timber	0,05	m3	0,5	0,17
UPN 180	0,5	p	1	24
Steel, converter, low-alloyed	18,888	kg	0,5	20
Hot rolling, steel	18,888	kg	0,5	2,6
Zinc coating, pieces	0,5817	m2	0,5	1,8
Steel Bracket	1	p	1	2,9
Steel, converter, low-alloyed	0,9444	kg	1	2
Hot rolling, steel	0,9444	kg	1	0,26
Zinc coating, pieces	0,097	m2	1	0,61
Wool insulation	1	p	1	4,8
Electricity, Italy	7,41	kWh	1	4,8
Tap water	119,7	kg	1	0
Polyester bands	0,5	p	1	16
PVC	16,56	kg	0,5	16

Use	Amount	Unit	Number	Impact
Product	1	p	1	1,6
Transport, lorry 16-32t, EURO5	7210,54	kgkm	1	1,1
Screw boards	1	p	1	0,5
Electricity, Italy	0,782	kWh	1	0,5

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden board	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
UPN 180	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Steel Bracket	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Wool insulation	70 %	0 %	30 %	0
Tap water				0
Polyester bands	100 %	0 %	0 %	0
PVC	100 %	0 %	0 %	0

COI_1

Total impact per phase (in kg CO2-eq):

Life cycle:	50
Production:	49
Use:	1,4
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	49
Wooden beams 200x50	0,5	p	1	0,92
Sawn timber, softwood	0,02	m3	0,5	0,86
Preservative treatment, sawn timber	0,02	m3	0,5	0,068
Screw+bolt	1	p	1	4,5
Steel, converter, unalloyed	2,07	kg	1	3,4
Section bar rolling, steel	2,07	kg	1	0,35
Zinc coating, pieces	135648	mm2	1	0,85
Timber frame	0,5	p	1	0,14
Sawn timber, softwood	0,0025	m3	0,5	0,11
Preservative treatment, sawn timber	0,0025	m3	0,5	0,0085
Electricity, Italy	0,09	kWh	0,5	0,029
Wooden boards 120x25	0,5	p	1	2,3
Sawn timber, softwood	0,049	m3	0,5	2,1
Preservative treatment, sawn timber	0,049	m3	0,5	0,17
UPN 240	0,5	p	1	39
Steel, converter, low-alloyed	33,054	kg	0,5	35
Hot rolling, steel	33,054	kg	0,5	4,6
Zinc coating, pieces	755,5	mm2	0,5	0,0024
Steel Bracket	1	p	1	1,6
Steel, converter, low-alloyed	0,35415	kg	1	0,75
Hot rolling, steel	0,35415	kg	1	0,098
Zinc coating, pieces	120000	mm2	1	0,75

Use	Amount	Unit	Number	Impact
Product	1	p	1	1,4
Transport, lorry 16-32t, EURO5	7480,315	kgkm	1	1,2
Screw boards	1	p	1	0,23
Electricity, Italy	0,366	kWh	1	0,23

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Wooden beams 200x50	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
UPN 240	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Steel Bracket	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0

COI_1A

Total impact per phase (in Pt):

Life cycle:	7,8
Production:	7,7
Use:	0,17
Disposal:	0

Detailed impacts per phase (all scores in Pt):

Production	Amount	Unit	Number	Impact
Product	1	p	1	7,7
Wooden beams 200x50	0,5	p	1	0,25
Sawn timber, softwood	0,02	m3	0,5	0,24
Preservative treatment, sawn timber	0,02	m3	0,5	0,0072
Screw+bolt	1	p	1	0,6
Steel, converter, unalloyed	2,19	kg	1	0,44
Section bar rolling, steel	2,19	kg	1	0,037
Zinc coating, pieces	143184	mm2	1	0,12
Timber frame	0,5	p	1	0,068
Sawn timber, softwood	0,0050	m3	0,5	0,06
Preservative treatment, sawn timber	0,0050	m3	0,5	0,0018
Electricity, Italy	0,18	kWh	0,5	0,006
Wooden boards 120x25	0,5	p	1	0,61
Sawn timber, softwood	0,049	m3	0,5	0,59
Preservative treatment, sawn timber	0,049	m3	0,5	0,018
UPN 240	0,5	p	1	5,2
Steel, converter, low-alloyed	33,054	kg	0,5	4,6
Hot rolling, steel	33,054	kg	0,5	0,53
Zinc coating, pieces	755,5	mm2	0,5	0,00033
Steel Bracket	1	p	1	0,21
Steel, converter, low-alloyed	0,35415	kg	1	0,1
Hot rolling, steel	0,35415	kg	1	0,011
Zinc coating, pieces	120000	mm2	1	0,1
Wool insulation	1	p	1	0,75
Electricity, Italy	11,115	kWh	1	0,74
Tap water	176,85	kg	1	0,0058

Use	Amount	Unit	Number	Impact
Product	1	p	1	0,17
Transport, lorry 16-32t, EURO5	8080,185	kgkm	1	0,14
Screw boards	1	p	1	0,026
Electricity, Italy	0,385	kWh	1	0,026

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Wooden beams 200x50	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
UPN 240	100 %	0 %	0 %	0

COI_2

Total impact per phase (in kg CO2-eq):

Life cycle:	18
Production:	17
Use:	0,95
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	17
Screw+bolt	1	p	1	3,3
Steel, converter, unalloyed	1,28	kg	1	2,1
Section bar rolling, steel	1,28	kg	1	0,22
Zinc coating, pieces	158818,84	mm2	1	0,99
Wooden boards 120x25	0,5	p	1	1,2
Sawn timber, softwood	0,025	m3	0,5	1,1
Preservative treatment, sawn timber	0,025	m3	0,5	0,085
Multicom Truss	0,5	p	1	11
Steel, low-alloyed	12	kg	0,5	11
Zinc coating, pieces	55822	mm2	0,5	0,17
Timber frame	0,5	p	1	0,098
Sawn timber, softwood	0,0017	m3	0,5	0,073
Preservative treatment, sawn timber	0,0017	m3	0,5	0,0058
Electricity, Italy	0,06	kWh	0,5	0,019
Wooden boards 300x40	0,5	p	1	1,8
Sawn timber, softwood	0,039	m3	0,5	1,7
Preservative treatment, sawn timber	0,039	m3	0,5	0,13

Use	Amount	Unit	Number	Impact
Product	1	p	1	0,95
Transport, lorry 16-32t, EURO5	4941,5	kgkm	1	0,76
Screw boards/frame	1	p	1	0,19
Electricity, Italy	0,293	kWh	1	0,19

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Multicom Truss	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Wooden boards 300x40	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0

COI_2A

Total impact per phase (in kg CO2-eq):

Life cycle:	23
Production:	22
Use:	1
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	22
Screw+bolt	1	p	1	3,3
Steel, converter, unalloyed	1,31	kg	1	2,1
Section bar rolling, steel	1,31	kg	1	0,22
Zinc coating, pieces	160828,44	mm2	1	1
Wooden boards 120x25	0,5	p	1	1,2
Sawn timber, softwood	0,025	m3	0,5	1,1
Preservative treatment, sawn timber	0,025	m3	0,5	0,085
Multicom Truss	0,5	p	1	11
Steel, low-alloyed	12	kg	0,5	11
Zinc coating, pieces	55822	mm2	0,5	0,17
Timber frame	0,5	p	1	0,2
Sawn timber, softwood	0,0034	m3	0,5	0,15
Preservative treatment, sawn timber	0,0034	m3	0,5	0,012
Electricity, Italy	0,12	kWh	0,5	0,039
Wooden boards 300x40	0,5	p	1	1,8
Sawn timber, softwood	0,039	m3	0,5	1,7
Preservative treatment, sawn timber	0,039	m3	0,5	0,13
Wool insulation	1	p	1	4,8
Electricity, Italy	7,41	kWh	1	4,8
Tap water	119,7	kg	1	0

Use	Amount	Unit	Number	Impact
Product	1	p	1	1
Transport, lorry 16-32t, EURO5	5459,5	kgkm	1	0,84
Screw boards/frame	1	p	1	0,2
Electricity, Italy	0,311	kWh	1	0,2

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Multicom Truss	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Wooden boards 300x40	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Wool insulation	70 %	0 %	30 %	0
Tap water				0

COI_3

Total impact per phase (in kg CO2-eq):

Life cycle:	43
Production:	42
Use:	1,3
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	42
Screw+bolt	1	p	1	4,5
Steel, converter, unalloyed	1,766	kg	1	2,9
Section bar rolling, steel	1,766	kg	1	0,3
Zinc coating, pieces	?17088,08	mm2	1	1,4
Wooden boards 120x25	0,5	p	1	2,3
Sawn timber, softwood	0,05	m3	0,5	2,1
Preservative treatment, sawn timber	0,05	m3	0,5	0,17
Tubolar scaffolding	0,5	p	1	16
Steel, low-alloyed	15,152	kg	0,5	13
Zinc coating, pieces	942000	mm2	0,5	2,9
Timber frame	0,5	p	1	0,14
Sawn timber, softwood	0,0025	m3	0,5	0,11
Preservative treatment, sawn timber	0,0025	m3	0,5	0,0085
Electricity, Italy	0,09	kWh	0,5	0,029
Scaffolding joints	0,5	p	1	18
Steel, converter, low-alloyed	10,36	kg	0,5	11
Hot impact extrusion, steel	10,36	kg	0,5	5,3
Zinc coating, pieces	527520	mm2	0,5	1,6
Wooden board 200x50	0,5	p	1	0,92
Sawn timber, softwood	0,02	m3	0,5	0,86
Preservative treatment, sawn timber	0,02	m3	0,5	0,068

Use	Amount	Unit	Number	Impact
Product	1	p	1	1,3
Transport, lorry 16-32t, EURO5	6715,3	kgkm	1	1
Screw boards/frame	1	p	1	0,31
Electricity, Italy	0,4888	kWh	1	0,31

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Tubolar scaffolding	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Scaffolding joints	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Wooden board 200x50	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0

COI_3A

Total impact per phase (in kg CO2-eq):

Life cycle:	49
Production:	47
Use:	1,5
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	47
Screw+bolt	1	p	1	4,6
Steel, converter, unalloyed	1,802	kg	1	2,9
Section bar rolling, steel	1,802	kg	1	0,3
Zinc coating, pieces	?19348,88	mm2	1	1,4
Wooden boards 120x25	0,5	p	1	2,3
Sawn timber, softwood	0,05	m3	0,5	2,1
Preservative treatment, sawn timber	0,05	m3	0,5	0,17
Tubolar scaffolding	0,5	p	1	16
Steel, low-alloyed	15,152	kg	0,5	13
Zinc coating, pieces	942000	mm2	0,5	2,9
Timber frame	0,5	p	1	0,26
Sawn timber, softwood	0,0050	m3	0,5	0,21
Preservative treatment, sawn timber	0,0050	m3	0,5	0,017
Electricity, Italy	0,09	kWh	0,5	0,029
Scaffolding joints	0,5	p	1	18
Steel, converter, low-alloyed	10,36	kg	0,5	11
Hot impact extrusion, steel	10,36	kg	0,5	5,3
Zinc coating, pieces	527520	mm2	0,5	1,6
Wooden board 200x50	0,5	p	1	0,92
Sawn timber, softwood	0,02	m3	0,5	0,86
Preservative treatment, sawn timber	0,02	m3	0,5	0,068
Wool insulation	1	p	1	4,8
Electricity, Italy	7,41	kWh	1	4,8
Tap water	119,7	kg	1	0

Use	Amount	Unit	Number	Impact
Product	1	p	1	1,5
Transport, lorry 16-32t, EURO5	7508,4	kgkm	1	1,2
Screw boards/frame	1	p	1	0,33
Electricity, Italy	0,5071	kWh	1	0,33

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Tubolar scaffolding	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Scaffolding joints	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Wooden board 200x50	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Wool insulation	70 %	0 %	30 %	0
Tap water				

COI_3B

Total impact per phase (in kg CO2-eq):

Life cycle:	133
Production:	131
Use:	2,6
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	131
Screw+bolt	1	p	1	0,83
Steel, converter, unalloyed	0,3636	kg	1	0,59
Section bar rolling, steel	0,3636	kg	1	0,061
Zinc coating, pieces	28844,04	mm2	1	0,18
Wooden boards 120x25	0,5	p	1	1,2
Sawn timber, softwood	0,025	m3	0,5	1,1
Preservative treatment, sawn timber	0,025	m3	0,5	0,085
Tubolar scaffolding	0,5	p	1	3,2
Steel, low-alloyed	2,976	kg	0,5	2,6
Zinc coating, pieces	188400	mm2	0,5	0,59
Timber frame	0,5	p	1	0,14
Sawn timber, softwood	0,0025	m3	0,5	0,11
Preservative treatment, sawn timber	0,0025	m3	0,5	0,0085
Electricity, Italy	0,09	kWh	0,5	0,029
Wooden board 200x50	0,5	p	1	2,3
Sawn timber, softwood	0,05	m3	0,5	2,1
Preservative treatment, sawn timber	0,05	m3	0,5	0,17
C beams	0,5	p	1	113
Steel, converter, low-alloyed	88	kg	0,5	93
Hot rolling, steel	88	kg	0,5	12
Zinc coating, pieces	2,692	m2	0,5	8,4
Crosshead	0,5	p	1	9,6
Steel, low-alloyed	10	kg	0,5	8,8
Zinc coating, pieces	?41216,22	mm2	0,5	0,75

Use	Amount	Unit	Number	Impact
Product	1	p	1	2,6
Transport, lorry 16-32t, EURO5	14424,86	kgkm	1	2,2
Screw boards/frame	1	p	1	0,36
Electricity, Italy	0,556	kWh	1	0,36

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Tubolar scaffolding	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Wooden board 200x50	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
C beams	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Crosshead	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0

COI_3C

Total impact per phase (in kg CO2-eq):

Life cycle:	48
Production:	47
Use:	1,3
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	47
Screw+bolt	1	p	1	10
Steel, converter, unalloyed	4,067	kg	1	6,6
Section bar rolling, steel	4,067	kg	1	0,68
Zinc coating, pieces	515012,84	mm2	1	3,2
Wooden boards 120x25	0,5	p	1	1,2
Sawn timber, softwood	0,025	m3	0,5	1,1
Preservative treatment, sawn timber	0,025	m3	0,5	0,085
Tubolar scaffolding	0,5	p	1	16
Steel, low-alloyed	15,152	kg	0,5	13
Zinc coating, pieces	942000	mm2	0,5	2,9
Timber frame	0,5	p	1	0,14
Sawn timber, softwood	0,0025	m3	0,5	0,11
Preservative treatment, sawn timber	0,0025	m3	0,5	0,0085
Electricity, Italy	0,09	kWh	0,5	0,029
Scaffolding joints	0,5	p	1	17
Steel, converter, low-alloyed	9,58	kg	0,5	10
Hot impact extrusion, steel	9,58	kg	0,5	4,9
Zinc coating, pieces	527520	mm2	0,5	1,6
Wooden board 200x50	0,5	p	1	2,3
Sawn timber, softwood	0,05	m3	0,5	2,1
Preservative treatment, sawn timber	0,05	m3	0,5	0,17

Use	Amount	Unit	Number	Impact
Product	1	p	1	1,3
Transport, lorry 16-32t, EURO5	7142,4	kgkm	1	1,1
Screw boards/frame	1	p	1	0,23
Electricity, Italy	0,354	kWh	1	0,23

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Tubolar scaffolding	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Scaffolding joints	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Wooden board 200x50	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0

COs_1

Total impact per phase (in kg CO2-eq):

Life cycle:	39
Production:	37
Use:	1,3
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	37
Wooden beams 200x50	0,5	p	1	0,92
Sawn timber, softwood	0,02	m3	0,5	0,86
Preservative treatment, sawn timber	0,02	m3	0,5	0,068
Screw+bolt	1	p	1	0,64
Steel, converter, unalloyed	0,273	kg	1	0,44
Section bar rolling, steel	0,273	kg	1	0,046
Zinc coating, pieces	23650,48	mm2	1	0,15
Wooden boards 120x25	0,5	p	1	2,6
Sawn timber, softwood	0,05598	m3	0,5	2,4
Preservative treatment, sawn timber	0,05598	m3	0,5	0,19
Steel Bracket	1	p	1	2,5
Steel, converter, low-alloyed	0,787	kg	1	1,7
Hot rolling, steel	0,787	kg	1	0,22
Zinc coating, pieces	100000	mm2	1	0,63
Corrugated sheet	0,5	p	1	31
Steel, converter, unalloyed	21,249	kg	0,5	17
Hot rolling, steel	21,249	kg	0,5	3
Zinc coating, pieces	3,33	m2	0,5	10

Use	Amount	Unit	Number	Impact
Product	1	p	1	1,3
Transport, lorry 16-32t, EURO5	6409,8	kgkm	1	0,99
Screw boards	1	p	1	0,29
Electricity, Italy	0,458	kWh	1	0,29

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Wooden beams 200x50	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Steel Bracket	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Corrugated sheet	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0

COs_1A

Total impact per phase (in kg CO2-eq):

Life cycle:	47
Production:	46
Use:	1,3
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	46
Wooden beams 200x50	0,5	p	1	0,92
Sawn timber, softwood	0,02	m3	0,5	0,86
Preservative treatment, sawn timber	0,02	m3	0,5	0,068
Screw+bolt	1	p	1	0,64
Steel, converter, unalloyed	0,273	kg	1	0,44
Section bar rolling, steel	0,273	kg	1	0,046
Zinc coating, pieces	23650,48	mm2	1	0,15
Wooden boards 120x25	0,5	p	1	2,4
Sawn timber, softwood	0,053	m3	0,5	2,3
Preservative treatment, sawn timber	0,053	m3	0,5	0,18
Steel Bracket	1	p	1	6,5
Steel, converter, low-alloyed	2,361	kg	1	5
Hot rolling, steel	2,361	kg	1	0,66
Zinc coating, pieces	145000	mm2	1	0,91
Corrugated sheet	0,5	p	1	31
Steel, converter, unalloyed	21,249	kg	0,5	17
Hot rolling, steel	21,249	kg	0,5	3
Zinc coating, pieces	3,33	m2	0,5	10
Wool insulation	1	p	1	4,8
Electricity, Italy	7,41	kWh	1	4,8
Tap water	117,9	kg	1	0
Timber frame	0,5	p	1	0,14
Sawn timber, softwood	0,0025	m3	0,5	0,11
Preservative treatment, sawn timber	0,0025	m3	0,5	0,0085
Electricity, Italy	0,09	kWh	0,5	0,029

Use	Amount	Unit	Number	Impact
Product	1	p	1	1,3
Transport, lorry 16-32t, EURO5	6839,7	kgkm	1	1,1
Screw boards	1	p	1	0,29
Electricity, Italy	0,458	kWh	1	0,29

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Wooden beams 200x50	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Steel Bracket	100 %	0 %	0 %	0
Steel, converter, low-alloyed	100 %	0 %	0 %	0
Corrugated sheet	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wool insulation	70 %	0 %	30 %	0
Tap water				0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0

COs_2

Total impact per phase (in kg CO2-eq):

Life cycle:	82
Production:	80
Use:	2,1
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	80
Tierod+ bolt	0,5	p	1	17
Steel, converter, unalloyed	17,01	kg	0,5	14
Section bar rolling, steel	17,01	kg	0,5	1,4
Zinc coating, pieces	480420	mm2	0,5	1,5
Wooden boards 120x25	0,5	p	1	2,5
Sawn timber, softwood	0,054	m3	0,5	2,3
Preservative treatment, sawn timber	0,054	m3	0,5	0,18
Multicom Truss	0,5	p	1	11
Steel, low-alloyed	12	kg	0,5	11
Zinc coating, pieces	55822	mm2	0,5	0,17
Wooden boards 300x40	0,5	p	1	1,1
Sawn timber, softwood	0,024	m3	0,5	1
Preservative treatment, sawn timber	0,024	m3	0,5	0,082
Corrugated sheet	0,5	p	1	31
Steel, converter, unalloyed	21,249	kg	0,5	17
Hot rolling, steel	21,249	kg	0,5	3
Zinc coating, pieces	3,33	m2	0,5	10
Tubolar scaffolding	0,5	p	1	6,2
Steel, low-alloyed	5,94	kg	0,5	5,2
Zinc coating, pieces	314000	mm2	0,5	0,98
Scaffolding joints	0,5	p	1	8,6
Steel, converter, low-alloyed	5	kg	0,5	5,3
Hot impact extrusion, steel	5	kg	0,5	2,6
Zinc coating, pieces	234453	mm2	0,5	0,73
Screw+ bolt	1	p	1	3,3
Steel, converter, unalloyed	1,29	kg	1	2,1
Section bar rolling, steel	1,29	kg	1	0,22
Zinc coating, pieces	161626	mm2	1	1

Use	Amount	Unit	Number	Impact
Product	1	p	1	2,1
Transport, lorry 16-32t, EURO5	10538,9	kgkm	1	1,6
Drill boards	1	p	1	0,21
Electricity, Italy	0,32	kWh	1	0,21
Screw boards	1	p	1	0,26
Electricity, Italy	0,40	kWh	1	0,26

COs_2

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Tierod+ bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Multicom Truss	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Wooden boards 300x40	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Corrugated sheet	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Tubolar scaffolding	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Scaffolding joints	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Screw+ bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0

COs_2A

Total impact per phase (in kg CO2-eq):

Life cycle:	87
Production:	84
Use:	2,1
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	84
Tierod+ bolt	0,5	p	1	17
Steel, converter, unalloyed	17,01	kg	0,5	14
Section bar rolling, steel	17,01	kg	0,5	1,4
Zinc coating, pieces	480420	mm2	0,5	1,5
Wooden boards 120x25	0,5	p	1	2,5
Sawn timber, softwood	0,054	m3	0,5	2,3
Preservative treatment, sawn timber	0,054	m3	0,5	0,18
Multicom Truss	0,5	p	1	11
Steel, low-alloyed	12	kg	0,5	11
Zinc coating, pieces	55822	mm2	0,5	0,17
Wooden boards 300x40	0,5	p	1	1,1
Sawn timber, softwood	0,024	m3	0,5	1
Preservative treatment, sawn timber	0,024	m3	0,5	0,082
Corrugated sheet	0,5	p	1	31
Steel, converter, unalloyed	21,249	kg	0,5	17
Hot rolling, steel	21,249	kg	0,5	3
Zinc coating, pieces	3,33	m2	0,5	10
Tubolar scaffolding	0,5	p	1	6,2
Steel, low-alloyed	5,94	kg	0,5	5,2
Zinc coating, pieces	314000	mm2	0,5	0,98
Scaffolding joints	0,5	p	1	8,6
Steel, converter, low-alloyed	5	kg	0,5	5,3
Hot impact extrusion, steel	5	kg	0,5	2,6
Zinc coating, pieces	234453	mm2	0,5	0,73
Screw+ bolt	1	p	1	3,3
Steel, converter, unalloyed	1,29	kg	1	2,1
Section bar rolling, steel	1,29	kg	1	0,22
Zinc coating, pieces	161626	mm2	1	1
Wool insulation	1	p	1	4,8
Electricity, Italy	7,41	kWh	1	4,8
Tap water	117,9	kg	1	0

Use	Amount	Unit	Number	Impact
Product	1	p	1	2,1
Transport, lorry 16-32t, EURO5	10838,9	kgkm	1	1,7
Drill boards	1	p	1	0,21
Electricity, Italy	0,32	kWh	1	0,21
Screw boards	1	p	1	0,26
Electricity, Italy	0,40	kWh	1	0,26

COs_2A

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Tierod+ bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Multicom Truss	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Wooden boards 300x40	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Corrugated sheet	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Tubolar scaffolding	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Scaffolding joints	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Screw+ bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wool insulation	70 %	0 %	30 %	0
Tap water				0

COs_2B

Total impact per phase (in kg CO2-eq):

Life cycle:	152
Production:	149
Use:	2,8
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	149
Tierod+ bolt	0,5	p	1	17
Steel, converter, unalloyed	17,01	kg	0,5	14
Section bar rolling, steel	17,01	kg	0,5	1,4
Zinc coating, pieces	480420	mm2	0,5	1,5
Wooden boards 120x25	0,5	p	1	2,3
Sawn timber, softwood	0,05	m3	0,5	2,1
Preservative treatment, sawn timber	0,05	m3	0,5	0,17
Multicom Truss	0,5	p	1	11
Steel, low-alloyed	12	kg	0,5	11
Zinc coating, pieces	55822	mm2	0,5	0,17
Wooden boards 300x40	0,5	p	1	1,1
Sawn timber, softwood	0,024	m3	0,5	1
Preservative treatment, sawn timber	0,024	m3	0,5	0,082
Corrugated sheet	0,5	p	1	31
Steel, converter, unalloyed	21,249	kg	0,5	17
Hot rolling, steel	21,249	kg	0,5	3
Zinc coating, pieces	3,33	m2	0,5	10
Screw+ bolt	1	p	1	3,3
Steel, converter, unalloyed	1,29	kg	1	2,1
Section bar rolling, steel	1,29	kg	1	0,22
Zinc coating, pieces	161626	mm2	1	1
C beams	0,5	p	1	76
Steel, converter, low-alloyed	58,66	kg	0,5	62
Hot rolling, steel	58,66	kg	0,5	8,2
Zinc coating, pieces	1,79	m2	0,5	5,6
Crosshead	0,5	p	1	8,5
Steel, low-alloyed	8,88	kg	0,5	7,8
Zinc coating, pieces	214200	mm2	0,5	0,67

Use	Amount	Unit	Number	Impact
Product	1	p	1	2,8
Transport, lorry 16-32t, EURO5	15859,9	kgkm	1	2,4
Drill boards	1	p	1	0,21
Electricity, Italy	0,32	kWh	1	0,21
Screw boards	1	p	1	0,19
Electricity, Italy	0,293	kWh	1	0,19

COs_2B

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Tierod+ bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Multicom Truss	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Wooden boards 300x40	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Corrugated sheet	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Screw+ bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
C beams	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Crosshead	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0

COs_2c

Total impact per phase (in kg CO2-eq):

Life cycle:	77
Production:	75
Use:	2
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	75
Tierod+ bolt	0,5	p	1	17
Steel, converter, unalloyed	17,01	kg	0,5	14
Section bar rolling, steel	17,01	kg	0,5	1,4
Zinc coating, pieces	480420	mm2	0,5	1,5
Wooden boards 120x25	0,5	p	1	2,5
Sawn timber, softwood	0,054	m3	0,5	2,3
Preservative treatment, sawn timber	0,054	m3	0,5	0,18
Multicom Truss	0,5	p	1	11
Steel, low-alloyed	12	kg	0,5	11
Zinc coating, pieces	55822	mm2	0,5	0,17
Wooden boards 300x40	0,5	p	1	1,1
Sawn timber, softwood	0,024	m3	0,5	1
Preservative treatment, sawn timber	0,024	m3	0,5	0,082
Corrugated sheet	0,5	p	1	31
Steel, converter, unalloyed	21,249	kg	0,5	17
Hot rolling, steel	21,249	kg	0,5	3
Zinc coating, pieces	3,33	m2	0,5	10
Tubolar scaffolding	0,5	p	1	3,8
Steel, low-alloyed	3,52	kg	0,5	3,1
Zinc coating, pieces	209333	mm2	0,5	0,65
Terminal joint	0,5	p	1	6,8
Steel, converter, low-alloyed	4	kg	0,5	4,2
Hot impact extrusion, steel	4	kg	0,5	2,1
Zinc coating, pieces	156302	mm2	0,5	0,49
Screw+ bolt	1	p	1	3,3
Steel, converter, unalloyed	1,29	kg	1	2,1
Section bar rolling, steel	1,29	kg	1	0,22
Zinc coating, pieces	161626	mm2	1	1

Use	Amount	Unit	Number	Impact
Product	1	p	1	2
Transport, lorry 16-32t, EURO5	10196,9	kgkm	1	1,6
Drill boards	1	p	1	0,21
Electricity, Italy	0,32	kWh	1	0,21
Screw boards	1	p	1	0,26
Electricity, Italy	0,40	kWh	1	0,26

COs_2c

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Tierod+ bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Multicom Truss	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Wooden boards 300x40	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Corrugated sheet	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Tubolar scaffolding	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Terminal joint	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Screw+ bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0

COs_3

Total impact per phase (in kg CO2-eq):

Life cycle:	104
Production:	102
Use:	2,1
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	102
Tierod+ bolt	0,5	p	1	4,3
Steel, converter, unalloyed	4,42	kg	0,5	3,6
Section bar rolling, steel	4,42	kg	0,5	0,37
Zinc coating, pieces	124909,2	mm2	0,5	0,39
Wooden boards 120x25	0,5	p	1	2,5
Sawn timber, softwood	0,054	m3	0,5	2,3
Preservative treatment, sawn timber	0,054	m3	0,5	0,18
Timber frame	0,5	p	1	0,14
Sawn timber, softwood	0,0025	m3	0,5	0,11
Preservative treatment, sawn timber	0,0025	m3	0,5	0,0085
Electricity, Italy	0,09	kWh	0,5	0,029
Corrugated sheet	0,5	p	1	31
Steel, converter, unalloyed	21,249	kg	0,5	17
Hot rolling, steel	21,249	kg	0,5	3
Zinc coating, pieces	3,33	m2	0,5	10
Tubolar scaffolding	0,5	p	1	36
Steel, low-alloyed	33,73	kg	0,5	30
Zinc coating, pieces	2135200	mm2	0,5	6,7
Scaffolding joints	0,5	p	1	28
Steel, converter, low-alloyed	15,92	kg	0,5	17
Hot impact extrusion, steel	15,92	kg	0,5	8,2
Zinc coating, pieces	879200	mm2	0,5	2,7
Screw+ bolt	1	p	1	0,6
Steel, converter, unalloyed	0,25	kg	1	0,41
Section bar rolling, steel	0,25	kg	1	0,042
Zinc coating, pieces	24278,48	mm2	1	0,15

Use	Amount	Unit	Number	Impact
Product	1	p	1	2,1
Transport, lorry 16-32t, EURO5	10664,4	kgkm	1	1,6
Drill boards/frame	1	p	1	0,045
Electricity, Italy	0,07	kWh	1	0,045
Screw boards	1	p	1	0,39
Electricity, Italy	0,60	kWh	1	0,39

COs_3

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Tierod+ bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Corrugated sheet	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Tubolar scaffolding	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Scaffolding joints	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Screw+ bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0

COs_3A

Total impact per phase (in kg CO2-eq):

Life cycle:	109
Production:	107
Use:	2,2
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	107
Tierod+ bolt	0,5	p	1	4,3
Steel, converter, unalloyed	4,42	kg	0,5	3,6
Section bar rolling, steel	4,42	kg	0,5	0,37
Zinc coating, pieces	124909,2	mm2	0,5	0,39
Wooden boards 120x25	0,5	p	1	2,5
Sawn timber, softwood	0,054	m3	0,5	2,3
Preservative treatment, sawn timber	0,054	m3	0,5	0,18
Timber frame	0,5	p	1	0,29
Sawn timber, softwood	0,0050	m3	0,5	0,21
Preservative treatment, sawn timber	0,0050	m3	0,5	0,017
Electricity, Italy	0,18	kWh	0,5	0,058
Corrugated sheet	0,5	p	1	31
Steel, converter, unalloyed	21,249	kg	0,5	17
Hot rolling, steel	21,249	kg	0,5	3
Zinc coating, pieces	3,33	m2	0,5	10
Tubolar scaffolding	0,5	p	1	36
Steel, low-alloyed	33,73	kg	0,5	30
Zinc coating, pieces	2135200	mm2	0,5	6,7
Scaffolding joints	0,5	p	1	28
Steel, converter, low-alloyed	15,92	kg	0,5	17
Hot impact extrusion, steel	15,92	kg	0,5	8,2
Zinc coating, pieces	879200	mm2	0,5	2,7
Screw+ bolt	1	p	1	0,6
Steel, converter, unalloyed	0,25	kg	1	0,41
Section bar rolling, steel	0,25	kg	1	0,042
Zinc coating, pieces	24278,48	mm2	1	0,15
Wool insulation	1	p	1	4,8
Electricity, Italy	7,41	kWh	1	4,8
Tap water	119,7	kg	1	0

Use	Amount	Unit	Number	Impact
Product	1	p	1	2,2
Transport, lorry 16-32t, EURO5	11101,9	kgkm	1	1,7
Drill boards/frame	1	p	1	0,06
Electricity, Italy	0,094	kWh	1	0,06
Screw boards	1	p	1	0,39
Electricity, Italy	0,60	kWh	1	0,39

COs_3A

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Tierod+ bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Corrugated sheet	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Tubolar scaffolding	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Scaffolding joints	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Screw+ bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wool insulation	70 %	0 %	30 %	0
Tap water				

COs_3B

Total impact per phase (in kg CO2-eq):

Life cycle:	164
Production:	161
Use:	2,8
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	161
Screw+bolt	1	p	1	0,55
Steel, converter, unalloyed	0,225	kg	1	0,36
Section bar rolling, steel	0,225	kg	1	0,038
Zinc coating, pieces	23022,48	mm2	1	0,14
Wooden boards 120x25	0,5	p	1	2,3
Sawn timber, softwood	0,05	m3	0,5	2,1
Preservative treatment, sawn timber	0,05	m3	0,5	0,17
Timber frame	0,5	p	1	0,14
Sawn timber, softwood	0,0025	m3	0,5	0,11
Preservative treatment, sawn timber	0,0025	m3	0,5	0,0085
Electricity, Italy	0,09	kWh	0,5	0,029
C beams	0,5	p	1	113
Steel, converter, low-alloyed	88	kg	0,5	93
Hot rolling, steel	88	kg	0,5	12
Zinc coating, pieces	2,692	m2	0,5	8,4
Crosshead	0,5	p	1	9,6
Steel, low-alloyed	10	kg	0,5	8,8
Zinc coating, pieces	241216,22	mm2	0,5	0,75
Tierod+bolt	0,5	p	1	4,3
Steel, converter, unalloyed	4,42	kg	0,5	3,6
Section bar rolling, steel	4,42	kg	0,5	0,37
Zinc coating, pieces	124909,2	mm2	0,5	0,39
Corrugated sheet	0,5	p	1	31
Steel, converter, unalloyed	21,249	kg	0,5	17
Hot rolling, steel	21,249	kg	0,5	3
Zinc coating, pieces	3,33	m2	0,5	10

Use	Amount	Unit	Number	Impact
Product	1	p	1	2,8
Transport, lorry 16-32t, EURO5	15276,9	kgkm	1	2,4
Screw boards	1	p	1	0,41
Electricity, Italy	0,64	kWh	1	0,41
Drill boards/frame	1	p	1	0,045
Electricity, Italy	0,07	kWh	1	0,045

COs_3B

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
C beams	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Crosshead	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Tierod+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Corrugated sheet	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0

COs_3c

Total impact per phase (in kg CO2-eq):

Life cycle:	109
Production:	107
Use:	2,3
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	107
Screw+bolt	1	p	1	0,61
Steel, converter, unalloyed	0,250	kg	1	0,41
Section bar rolling, steel	0,250	kg	1	0,042
Zinc coating, pieces	25534,48	mm2	1	0,16
Wooden boards 120x25	0,5	p	1	2,3
Sawn timber, softwood	0,05	m3	0,5	2,1
Preservative treatment, sawn timber	0,05	m3	0,5	0,17
Timber frame	0,5	p	1	0,14
Sawn timber, softwood	0,0025	m3	0,5	0,11
Preservative treatment, sawn timber	0,0025	m3	0,5	0,0085
Electricity, Italy	0,09	kWh	0,5	0,029
C beams	0,5	p	1	57
Steel, converter, low-alloyed	44	kg	0,5	46
Hot rolling, steel	44	kg	0,5	6,1
Zinc coating, pieces	1,346	m2	0,5	4,2
Crosshead	0,5	p	1	9,6
Steel, low-alloyed	10	kg	0,5	8,8
Zinc coating, pieces	?41216,22	mm2	0,5	0,75
Tierod+bolt	0,5	p	1	4,3
Steel, converter, unalloyed	4,42	kg	0,5	3,6
Section bar rolling, steel	4,42	kg	0,5	0,37
Zinc coating, pieces	124909,2	mm2	0,5	0,39
Corrugated sheet	0,5	p	1	31
Steel, converter, unalloyed	21,249	kg	0,5	17
Hot rolling, steel	21,249	kg	0,5	3
Zinc coating, pieces	3,33	m2	0,5	10
Wooden beams 50x200	0,5	p	1	0,92
Sawn timber, softwood	0,02	m3	0,5	0,86
Preservative treatment, sawn timber	0,02	m3	0,5	0,068
Steel bracket	1	p	1	1,6
Steel, converter, low-alloyed	0,35415	kg	1	0,75
Hot rolling, steel	0,35415	kg	1	0,098
Zinc coating, pieces	120000	mm2	1	0,75

Use	Amount	Unit	Number	Impact
Product	1	p	1	2,3
Transport, lorry 16-32t, EURO5	12014,82	kgkm	1	1,9
Screw boards	1	p	1	0,44
Electricity, Italy	0,68	kWh	1	0,44
Drill boards/frame	1	p	1	0,045
Electricity, Italy	0,07	kWh	1	0,045

COs_3c

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
C beams	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Crosshead	100 %	0 %	0 %	0
Steel, low-alloyed	100 %	0 %	0 %	0
Tierod+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Corrugated sheet	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wooden beams 50x200	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Steel bracket	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0

COs_4

Total impact per phase (in kg CO2-eq):

Life cycle:	82
Production:	80
Use:	2
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	80
Wooden beams 200x50	0,5	p	1	0,92
Sawn timber, softwood	0,02	m3	0,5	0,86
Preservative treatment, sawn timber	0,02	m3	0,5	0,068
Screw+bolt	1	p	1	4,8
Steel, converter, unalloyed	2,1687	kg	1	3,5
Section bar rolling, steel	2,1687	kg	1	0,36
Zinc coating, pieces	145696	mm2	1	0,91
Timber frame	0,5	p	1	0,14
Sawn timber, softwood	0,0025	m3	0,5	0,11
Preservative treatment, sawn timber	0,0025	m3	0,5	0,0085
Electricity, Italy	0,09	kWh	0,5	0,029
Wooden boards 120x25	0,5	p	1	2,6
Sawn timber, softwood	0,0565	m3	0,5	2,4
Preservative treatment, sawn timber	0,0565	m3	0,5	0,19
UPN 240	0,5	p	1	39
Steel, converter, low-alloyed	33,054	kg	0,5	35
Hot rolling, steel	33,054	kg	0,5	4,6
Zinc coating, pieces	755,5	mm2	0,5	0,0024
Steel Bracket	1	p	1	1,6
Steel, converter, low-alloyed	0,35415	kg	1	0,75
Hot rolling, steel	0,35415	kg	1	0,098
Zinc coating, pieces	120000	mm2	1	0,75
Corrugated sheet	0,5	p	1	31
Steel, converter, unalloyed	21,249	kg	0,5	17
Hot rolling, steel	21,249	kg	0,5	3
Zinc coating, pieces	3,33	m2	0,5	10

Use	Amount	Unit	Number	Impact
Product	1	p	1	2
Transport, lorry 16-32t, EURO5	10027,585	kgkm	1	1,5
Screw boards	1	p	1	0,42
Electricity, Italy	0,6593	kWh	1	0,42

COs_4

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Wooden beams 200x50	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
UPN 240	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Steel Bracket	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Corrugated sheet	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0

COs_4A

Total impact per phase (in kg CO2-eq):

Life cycle:	87
Production:	85
Use:	2
Disposal:	0

Detailed impacts per phase (all scores in kg CO2-eq):

Production	Amount	Unit	Number	Impact
Product	1	p	1	85
Wooden beams 200x50	0,5	p	1	0,92
Sawn timber, softwood	0,02	m3	0,5	0,86
Preservative treatment, sawn timber	0,02	m3	0,5	0,068
Screw+bolt	1	p	1	4,9
Steel, converter, unalloyed	2,2047	kg	1	3,6
Section bar rolling, steel	2,2047	kg	1	0,37
Zinc coating, pieces	147956,8	mm2	1	0,92
Timber frame	0,5	p	1	0,26
Sawn timber, softwood	0,0050	m3	0,5	0,21
Preservative treatment, sawn timber	0,0050	m3	0,5	0,017
Electricity, Italy	0,09	kWh	0,5	0,029
Wooden boards 120x25	0,5	p	1	2,6
Sawn timber, softwood	0,0565	m3	0,5	2,4
Preservative treatment, sawn timber	0,0565	m3	0,5	0,19
UPN 240	0,5	p	1	39
Steel, converter, low-alloyed	33,054	kg	0,5	35
Hot rolling, steel	33,054	kg	0,5	4,6
Zinc coating, pieces	755,5	mm2	0,5	0,0024
Steel Bracket	1	p	1	1,6
Steel, converter, low-alloyed	0,35415	kg	1	0,75
Hot rolling, steel	0,35415	kg	1	0,098
Zinc coating, pieces	120000	mm2	1	0,75
Corrugated sheet	0,5	p	1	31
Steel, converter, unalloyed	21,249	kg	0,5	17
Hot rolling, steel	21,249	kg	0,5	3
Zinc coating, pieces	3,33	m2	0,5	10
Wool insulation	1	p	1	4,8
Electricity, Italy	7,41	kWh	1	4,8
Tap water	119,7	kg	1	0

Use	Amount	Unit	Number	Impact
Product	1	p	1	2
Transport, lorry 16-32t, EURO5	10468,685	kgkm	1	1,6
Screw boards	1	p	1	0,44
Electricity, Italy	0,6776	kWh	1	0,44

COs_4A

Disposal	Recycling	Incineration	Landfill	Impact
Product	100 %	0 %	0 %	0
Wooden beams 200x50	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Screw+bolt	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Timber frame	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
Wooden boards 120x25	100 %	0 %	0 %	0
Sawn timber, softwood	100 %	0 %	0 %	0
UPN 240	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Steel Bracket	100 %	0 %	0 %	0
Steel, converter, low-alloyec	100 %	0 %	0 %	0
Corrugated sheet	100 %	0 %	0 %	0
Steel, converter, unalloyed	100 %	0 %	0 %	0
Wool insulation	70 %	0 %	30 %	0
Tap water				

APPENDIX_ E

TIE-ROD INTERVENTION WITH STEEL GRID			
Bominiaco Street			
Not reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
HEA 200	Length 0,70 m	27	High
HEA 200 (knee shape)	Length 2,40 m	1	Low
Double UPN 180	Length 0,20	3	High
Welded connections composed of:			
---HEA 200	Length 0,50 m	18	Average
---L brackets	200x200x16 mm		
---Locking edges-plates	150x150x10 mm		
---Double UPN 180	Length 0,20 m		
Welded connections composed of:			
---HEA 200	Length 0,60 m	8	Average
---L brackets	200x200x16 mm		
---Locking edges-plates	150x150x10 mm		
---Double UPN 180	Length 0,20 m		
Welded connections composed of:			
---HEA 200	Length 0,70 m	2	Average
---L bracket	200x200x16 mm		
---Locking edges-plates	150x150x10 mm		
---Double UPN 180	Length 0,20 m		
Welded connections composed of:			
---HEA 200	Length 0,90 m	2	Average
---L brackets	200x200x16 mm		
---Locking edges-plates	150x150x10 mm		
---Double UPN 180	Length 0,20 m		
Welded connections composed of:			
---HEA 200	Length 1,20 m	1	Average
---L brackets	200x200x16 mm		
---Locking edges-plates	150x150x10 mm		
---Double UPN 180	Length 0,20 m		
Welded connections composed of:			
---HEA 200	Length 0,50 m	1	Average
---L brackets	200x200x16 mm		
---Locking edges-plates	150x150x10 mm		
---Double UPN 180	Length 0,60 m		
Welded connections composed of:			
---HEA 200	Length 0,50 m	2	Average
---L brackets	200x200x16 mm		
---Locking edges-plates	150x150x10 mm		
---Double UPN 180	Length 0,35 m		

Corner elements (90°)			
---HEA 200	Length 0,70 m	2	High
---L brackets	200x200x16 mm		
---Locking edges-plates	150x150x10 mm		
---Double UPN 180	Length 0,95 m + Length 1,65 m		
---Steel plates	500x500x20 mm		
Corner elements (90°)			
---HEA 200	Length 0,95 m	1	High
---L brackets	200x200x16 mm		
---Locking edges-plates	150x150x10 mm		
---Double UPN 180	Length 0,95 m + Length 1,65 m		
---Steel plate	500x500x20 mm		
Corner elements (90°)			
---HEA 200	Length 1,30 m	1	High
---L brackets	200x200x16 mm		
---Locking edges-plates	150x150x10 mm		
---Double UPN 180	Length 0,95 m + Length 1,65 m		
---Steel plates	500x500x20 mm		
Wooden boards	20x5x50 cm	27	High
Reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
Double UPN 180	Length 0,80 m	1	Average
	Length 3,00 m	3	
	Length 4,90 m	6	
	Length 5,30 m	6	
	Length 5,60 m	4	
	Length 5,75 m	3	
	Length 6,00 m	7	
	Length 6,30 m	6	
HEA 200	Length 0,80 m	3	Low
	Length 1,0 m	1	
	Length 1,20 m	3	
	Length 1,50 m	1	
	Length 1,70 m	3	
	Length 2,0 m	14	
	Length 2,15 m	2	
	Length 2,30 m	2	
	Length 2,50 m	3	
	Length 2,60 m	1	
	Length 2,70 m	1	

HEA 200	Length 2,80 m	4	Low
	Length 3,20 m	3	
	Length 3,30 m	1	
	Length 3,50 m	1	
	Length 3,60 m	1	
	Length 3,90 m	2	
	Length 4,0 m	1	
	Length 4,30 m	1	
	Length 4,50 m	1	
	Length 4,80 m	2	
	Length 5,20 m	1	
	Length 5,40 m	15	
	Length 5,50 m	1	
	Length 6,0 m	3	
	Length 6,25 m	2	
	Length 6,35 m	2	
	Length 6,80 m	1	
	Length 6,90 m	1	
	Length 7,00 m	1	
	Length 7,30 m	1	
Steel plates	250x120x10 mm 4+4 M16x105	60	Low
	250x180x20 mm	60	
	215x120x6 mm 4+4 M14x55	54	
	285x200x10 mm 4+4 M20x50	54	
Wooden boards	20x5x380 cm	1	Low
	20x5x410 cm	1	
	20x5x430 cm	1	
	20x5x450 cm	1	
	20x5x465 cm	1	
	20x5x470 cm	1	
	20x5x490 cm	1	
	20x5x500 cm	1	
	20x5x520 cm	23	
	20x5x540 cm	1	
	20x5x560 cm	1	
	20x5x580 cm	2	
	20x5x590 cm	1	
	20x5x 600 cm	1	
	20x5x610 cm	1	
	20x5x620 cm	7	

	20x5x630 cm	1	
	20x5x650 cm	1	
	20x5x675 cm	3	
	20x5x695 cm	3	
	20x5x720 cm	1	
Steel tie-rods ϕ 22	Length 7,50 m	2	Low
	Length 8,10 m	3	
	Length 8,30 m	2	
	Length 8,50 m	3	
	Length 9,00 m	13	
	Length 10,20 m	3	
	Length 11,10 m	9	
	Length 11,50 m	3	
	Length 17,50 m	13	
	Length 19,50 m	3	
	Length 20,00 m	7	
Accursio Street			
Not reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
HEA 200	Length 0,70 m	5	High
Welded connections composed of:			
---HEA 200	Length 0,50 m	7	Average
---L brackets	200x200x16 mm		
---Locking edges-plates	150x150x10 mm		
---Double UPN 180	Length 0,20 m		
Welded connections composed of:			
---HEA 200	Length 1,00 m	1	Average
---L brackets	200x200x16 mm		
---Locking edges-platess	150x150x10 mm		
---Double UPN 180	Length 0,20 m		
Welded connections composed of:			
---HEA 200	Length 0,80 m	8	Average
---L bracket	200x200x16 mm		
---Locking edges-plates	150x150x10 mm		
---Double UPN 180	Length 0,20 m		
Welded connections composed of:			
---HEA 200	Length 0,30 m	2	Average
---L brackets	200x200x16 mm		
---Locking edges-plates	150x150x10 mm		
---Double UPN 180	Length 0,50 m		
Welded connections composed of:			
---HEA 200	Length 1,25 m		

---L brackets	200x200x16 mm	1	High
---Locking edges-plates	150x150x10 mm		
---Double UPN 180	Length 0,50 m		
Welded connections composed of:			
---HEA 200	Length 1,45 m	2	High
---L brackets	200x200x16 mm		
---Locking edges-plates	150x150x10 mm		
---Double UPN 180	Length 0,20 m		
Wooden boards	20x5x50 cm	8	High
Reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
Double UPN 180	Length 1,20 m	3	Average
	Length 1,60 m	3	
	Length 2,40 m	3	
	Length 3,80 m	3	
	Length 3,15 m	3	
	Length 0,90 m	3	High
HEA 200	Length 0,75 m	2	Low
	Length 1,05 m	2	
	Length 1,30 m	3	
	Length 1,95 m	7	
	Length 3,50 m	1	
	Length 3,80 m	1	
	Length 4,10 m	1	
	Length 4,30 m	3	
	Length 4,50 m	1	
	Length 5,10 m	1	
	Length 6,35 m	1	
Steel plates	250x120x10 mm 4+4 M16x105	24	Average
	250x180x20 mm	24	
	215x120x6 mm 4+4 M14x55	14	
	285x200x10 mm 4+4 M20x50	14	
Wooden boards	20x5x325 cm	3	Average
	20x5x350 cm	1	
	20x5x375 cm	1	
	20x5x400 cm	1	
	20x5x425 cm	2	
	20x5x500 cm	1	
	20x5x520 cm	4	
	20x5x620 cm	2	

Steel tie-rods ϕ 22	Length 7,90 m	1	Low
	Length 8,50 m	3	
	Length 9,00 m	1	
	Length 18,20 m	6	
	Length 18,70 m	7	
Coutyard- Bominiaco Street			
Not reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
HEA 200	Length 0,70 m	7	High
Welded connections composed of:			
---HEA 200	Length 0,50 m	6	Average
---L brackets	200x200x16 mm		
--Locking edges-plates	150x150x10 mm		
---Double UPN 180	Length 0,20 m		
Wooden boards	20x5x50 cm	7	High
Reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
Double UPN 180	Length 2,60 m	2	Average
	Length 3,30 m	2	
	Length 4,70 m	2	
	Length 5,25 m	2	
HEA 200	Length 0,80 m	3	Low
	Length 1,40 m	3	
	Length 1,50 m	3	
	Length 2,85 m	3	
	Length 3,35 m	4	
	Length 4,10 m	4	
Steel plates	250x120x10 mm 4+4 M16x105	12	Average
	250x180x20 mm	12	
	215x120x6 mm 4+4 M14x55	14	
	285x200x10 mm 4+4 M20x50	14	
Wooden boards	20x5x195 cm	1	Average
	20x5x205 cm	1	
	20x5x230 cm	1	
	20x5x255 cm	1	
	20x5x290 cm	1	
	20x5x310 cm	1	
	20x5x320 cm	1	
	20x5x400 cm	7	

Cortile lato via Accursio			
Not reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
HEA 200	Length 0,70 m	8	High
Welded connections composed of:			
---HEA 200	Length 0,50 m	6	Average
---L brackets	200x200x16 mm		
---Locking edges-plates	150x150x10 mm		
---Double UPN 180	Length 0,20 m		
Wooden boards	20x5x50 cm	8	High
Reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
Double UPN 180	Length 0,95 m	1	Average
	Length 3,40 m	3	
	Length 5,05 m	3	
	Length 5,55 m	2	
HEA 200	Length 1,0 m	2	Low
	Length 3,20 m	2	
	Length 4,0 m	2	
	Length 6,95 m	3	
	Length 9,70 m	3	
Steel plates	250x120x10 mm 4+4 M16x105	12	Average
	250x180x20 mm	12	
Wooden boards	20x5x695 cm	3	Average
	20x5x970 cm	5	
Coutyard- Vittorio Emanuele Street			
Not reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
Welded connections composed of:			
---HEA 200	Length 0,50 m	6[1]	Average
---L brackets	200x200x16 mm		
---Locking edges-plates	150x150x10 mm		
---Double UPN 180	Length 0,20 m		
HEA 200	Length 0,70 m	4	High
Double UPN 180	Length 0,3	1	Average
	Length 0,5	1	
Wooden boards	20x5x50 cm	4	High
Reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
HEA 200	Length 0,50 m	4	Low
	Length 1,30 m	12	
	Length 3,80 m	4	

	Length 4,70 m	4	
Double UPN 180	Length 1,0 m	2	Average
	Length 1,3 m	5	
	Length 1,6 m	1	
	Length 2,0 m	5	
	Length 2,8 m	4	
	Length 8,2 m	1	
Wooden boards[2]	-	-	-

TIE- ROD INTERVENT WITH WOODEN GRID			
Vittorio Emanuele Street			
Not reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
Wooden components	14x18x75 cm	50	Average
	14x18x120 cm	1	High
	20x20x50 cm	8	High
	20x20x75 cm	32	Average
	20x20x100 cm	12	High
Wooden boards	15x2,5x20 cm	2	High
	15x2,5x50 cm	22	
	15x5x20 cm	2	
	15x5x50 cm	22	
Reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
Wooden components	14x18x330 cm	2	Low
	14x18x440 cm	4	
	14x18x700 cm	2	
	14x18x900 cm	2	
	14x18x190 cm	1	Average
	14x18x330 cm	1	
	14x18x350 cm	1	
	14x18x440 cm	3	
	14x18x520	1	
	14x18x700 cm	2	
	14x18x800 cm	1	
	14x18x900 cm	2	
	14x18x190 cm	1	High
	14x18x330 cm	2	
	14x18x350 cm	3	
	14x18x440 cm	4	
	14x18x600 cm	2	
	14x18x700 cm	3	

	14x18x800 cm	1	
	14x18x900 cm	3	
	14x18x1000 cm	1	
	14x18x11700 cm	1	
	20x20x285 cm	4	Low
	20x020x525 cm	24	
	20x20x535 cm	2	
	20x20x545 cm	2	
	20x20x560 cm	2	
	20x20x570 cm	2	
	20x20x610 cm	2	
	20x20x620 cm	2	
Wooden boards	15x2,5x50 cm	8	Average
	15x2,5x60 cm	10	
	15x2,5x70 cm	22	
	15x2,5x80 cm	5	
	15x2,5x100 cm	36	
	15x2,5x120 cm	2	
	15x2,5x140 cm	7	
	15x2,5x190 cm	8	
	15x2,5x220 cm	2	
	15x2,5x250 cm	5	
	15x2,5x330 cm	8	
	15x2,5x350 cm	6	
	15x2,5x450 cm	18	
	15x2,5x490 cm	2	
	15x2,5x610 cm	2	
	15x2,5x665 cm	6	
	15x2,5x1000 cm	2	
	15x5x50 cm	8	
	15x5x60 cm	10	
	15x5x70 cm	22	
	15x5x80 cm	5	
	15x5x100 cm	36	
	15x5x120 cm	2	
	15x5x140 cm	7	
	15x5x190 cm	8	
	15x5x220 cm	2	
	15x5x250 cm	5	
	15x5x330 cm	8	
	15x5x350 cm	6	
	15x5x450 cm	18	

	15x5x490 cm	2	
	15x5x610 cm	2	
	15x5x665 cm	6	
	15x5x1000 cm	2	
Steel sheets (C shape)	20x150x0,3 cm	41	Low
Steel plates	50x50x2 cm	34	Low
C stell brackets	15x15x – cm (ipotesi spessore 6 mm)	95	Low In alcuni rari casi il degrado è alto.
Steel tie-rods ϕ 22	Length 8,60 m	1	Low
	Length 10,00 m	3	
	Length 10,30 m	2	
	Length 11,00 m	3	
	Length 12,30 m	26	
	Length 16,70 m	2	
	Length 19,60 m	1	

HOOPING INTERVENTION WITH POLYESTER BANDS			
Corutyard- Accursio street			
Reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
Polyester bands	Length tra 10 e 15 metri	9	Low
	Length 40 metri	1	
Load hooks	-	10	Low
Steel angular profiles[3]	-	-	-
Wooden boards[4]	-	-	-

REINFORCEMENT OF OPENINGS[5]			
Bominiaco Street			
Not reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
Wooden components	10x10x10 cm	216	Low
	10x10x20 cm	6	
	10x10x50 cm	21	High
	10x10x100 cm	7	
	10x10x160 cm	1	
	10x10x180 cm	1	
Reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
Wooden components	10x10x75 cm	12	Low
	10x10x80 cm	24	
	10x10x110 cm	8	
	10x10x150 cm	7	

	10x10x170 cm	22	
	10x10x190 cm	38	
	10x10x210 cm	4	
	10x10x230 cm	4	
	10x10x290 cm	6	
Via Accursio			
Not reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
Wooden components	10x10x10 cm	12	High
	10x10x50 cm	4	
	10x10x100 cm	1	
	10x10x180 cm	1	
Reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
Wooden components	10x10x100 cm	1	Low
	10x10x180 cm	1	
	10x10x300 cm	4	
	10x10x360 cm	5	
Coutyard - Accursio street			
Not reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
Wooden components	10x10x10 cm	242	High
	10x10x50 cm	12	
	10x10x90 cm	2	
	10x10x220 cm	1	
Reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
Wooden components	10x10x70 cm	18	Low
	10x10x80 cm	40	
	10x10x120 cm	60	
	10x10x200 cm	1	
	10x10x220 cm	8	
	10x10x350 cm	4	
Vittorio Emanuele Street			
Not reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
Wooden components	10x10x10 cm	126	High
	10x10x20 cm	8	
	10x10x50 cm	22	
	10x10x180 cm	1	
Wooden boards	10x3x210 cm	6	High

Reusable components			
Typology	Dimensions	Quantity (n.)	Deterioration
Wooden components	10x10x100 cm	10	Low
	10x10x120 cm	30	
	10x10x150 cm	9	
	10x10x200 cm	2	
	10x10x230 cm	22	
	10x10x300 cm	9	
	10x10x350 cm	4	
	10x10x380 cm	2	
Indoor			
Not reusable components			
Typology	Dimensions	Quantity (n.)	
Wooden components	10x10x10 cm	815	
Reusable components			
Typology	Dimensions	Quantity (n.)	
Wooden components	10x10x80 cm	26	
	10x10x90 cm	4	
	10x10x100 cm	48	
	10x10x110 cm	26	
	10x10x120 cm	67	
	10x10x130 cm	50	
	10x10x140 cm	10	
	10x10x150 cm	10	
	10x10x160 cm	8	
	10x10x170 cm	164	
	10x10x190 cm	64	
	10x10x400 cm	16	

TELESCOPIC PROPS		
Indoor		
Reusable components		
Typology	Dimensions	Quantity (n.)
Adjustable telescopic steel props	Lenght until 5,40 m	202
Steel tubulars	Length 1,0 m	3
	Length 1,10 m	1
	Length 1,30 m	1
	Length 1,50 m	1
	Length 1,60 m	6
	Length 1,70 m	3
	Length 1,90 m	10

Steel tubulars	Length 2,00 m	5
	Length 2,20 m	6
	Length 2,60 m	2
	Length 2,80 m	3
	Length 2,90 m	1
	Length 3,20 m	1
	Length 3,40 m	3
	Length 3,60 m	9
	Length 4,30 m	4
	Length 4,60 m	5
	Length 5,20 m	12
	Length 5,50 m	11
	Length 5,60 m	3
	Length 6,0 m	15
Right angle clamps		271
Wooden boards[6]	15x2,5x70 cm	4
	15x2,5x100 cm	8
	15x2,5x120 cm	8
	15x2,5x140 cm	28
	15x2,5x160 cm	14
	115x2,5x190 cm	4
	15x2,5x210 cm	14
	15x2,5x220 cm	16
	15x2,5x240 cm	4
	15x2,5x350 cm	10
	15x2,5x380 cm	4
	15x2,5x400 cm	154

TUBE-CLAMP SYSTEM[7]		
Indoor		
Reusable components		
Typology	Dimensions	Quantity (n.)
Steel tubulars	Length 0,50 m	660
	Length 0,85 m	12
	Length 1,30 m	6
	Length 1,50 m	12
	Length 2,00 m	30
	Length 3,50 m	40
	Length 4,30 m	400
	Length 5,50 m	6
	Length 6,00 m	72
Right angle clamps	-	2568

COVERAGE[8]		
Coutyard		
Reusable components		
Typology	Dimensions	Quantity (n.)
Corrugated sheets	30 mq	1

NOTES

1. *The determination is made compared to "Courtyard Accursio street".*
2. *From the available information, it is not possible to know the size of the load distribution boards.*
3. *From the available information, it is not possible to know the dimensions of the angular steel profile.*
4. *From the available information, it is not possible to know the dimensions of the angular wooden boards.*
5. *When there are not informations about the height of the windows, it is considered equal to the width. The case occurs in a limited number of openings located inside the building.*
6. *We have only the total length of the wooden boards and we don't have the partial length of these, it is considered a standard length of 4.00 m and we measure the remaining length compared to the standard lenght of the room.*
7. *We don't have the sections of the building that would show more accurately the assembly scheme of the tubular scaffoldings and we cannot access in the building to make the survey. However we consider the tubular scaffoldings mounted according to standard schemes. We consider a vertical element for each intersection between the horizontal elements, as represented in the plan drawing. The length of the vertical tubulars is considered equal to the height of the room, the length of the horizontal tubulars is measured in the plan drawing, when it exceeds the value of 6 meters, that is the maximum length produced, we consider two elements one of length equal to 6 meters, and the other of the remaining length to reach the total. In function of the height of the room and consequently of the tubular systems, we define the number of the horizontal tubulars. In the mezzanine, in the first floor and the second floor are considered a number of 3 horizontal tubular. The calculation of wooden boards used for load distribution between the vertical tubes and the floor and between them and the ceiling is neglectes, because we dont'have information to estimate probable.*
8. *As indicated in the plan drawing, that is deposited in the "Ufficio Messa in Sicurezza Centro Storico del Comune di L'Aquila", the coverage is sustained in the middle by a stiffening castle made of steel tubular and joints and by the walls along the perimeter.*

APPENDIX_ F

CHANGING ROOM		
Typology	Dimensions	Quantity (n.)
Wooden boards	15x2,5x30 cm	16
	15x2,5x90 cm	9
	15x2,5x110 cm	4
	15x2,5x130 cm	8
	15x2,5x260 cm	38
	15x2,5x310 cm	34
	15x2,5x310 cm	6
	15x2,5x330 cm	17
	15x2,5x370 cm	32
	15x2,5x440 cm	23
	15x2,5x450 cm	32
	15x2,5x470 cm	4
	15x5x110 cm	4
	15x5x130 cm	8
	15x5x330 cm	21
	15x5x370 cm	27
	20x5x110 cm	4
	20x5x130 cm	13
	20x5x260 cm	8
	20x5x300 cm	8
	20x5x330 cm	25
	20x5x370 cm	42
	20x5x470 cm	13
Wooden elements	5x5x250 cm	5
	5x5x300 cm	27
	5x5x450 cm	4
	10x10x260 cm	4
	10x10x300 cm	4
Wooden beams	14x18x110 cm	2
	14x18x130 cm	3
	14x18x330 cm	8
	14x18x370 cm	19
	20x20x100 cm	1
	20x20x120 cm	1
	20x20x330 cm	6
	20x20x370 cm	6
UPN 240	2,60 m	4
	5,20 m	4
Tie-rods ϕ 22mm	5,30 m	6
Steel plates	150x150x6 mm	12

L bracket	150x150x150x6mm	12
	200x300x200x6mm	32
C bracket	200x200x200x6mm	8
U profile for false ceiling	10x10xh variabile	12
Insulation	90x100x5 cm	84
	80x100x5 cm	30
	80x100x10 cm	18
Corrugated sheet	5,5x4,30 m	1
Locking steel pates	200x200x6 mm	4
Screw piles	8 cm (diametro)	4
Window fixtures	Porta 2,10x0,90	1
	Finestra 1,40x0,80	1

RESTROOM		
Typology	Dimensions	Quantity (n.)
Wooden boards	15x2,5x15 cm	64
	15x2,5x60 cm	48
	15x2,5x180 cm	20
	15x2,5x210 cm	16
	15x2,5x270 cm	3
	15x2,5x350 cm	60
	15x2,5x375 cm	30
	15x2,5x415 cm	8
	15x2,5x475 cm	40
	15x2,5x500 cm	25
	15x2,5x550 cm	5
	20x5x515 cm	10
Wooden components	5x5x295 cm	30
	5x5x375 cm	15
	5x5x500 cm	15
	10x10x270 cm	22
	10x10x300 cm	20
Wooden beams	15x20x300 cm	2
MDF boards	15x2,5x85 cm	9
	15x2,5x90 cm	20
	15x2,5x120 cm	18
Alveolar polycarbonate panels	90x40x1,5 cm	3
	90x100x1,5 cm	75
	90x120x1,5 cm	12
	90x140x1,5 cm	12
Steel tubulars	Length 0,4 m	16
	Length 0,5 m	4

	Length 0,6 m	4
	Length 0,75 m	6
	Length 0,85 m	4
	Length 1,0 m	6
	Length 1,2 m	29
	Length 1,4 m	4
	Length 1,5 m	29
	Length 1,7 m	57
	Length 1,8 m	2
	Length 2,0 m	7
	Length 2,7 m	1
	Length 3,5 m	2
	Length 3,9 m	6
	Length 4,0 m	2
	Length 4,1 m	2
	Length 4,4 m	2
	Length 4,5 m	10
	Length 5,3 m	22
	Length 5,5 m	3
	Length 6,0 m	6
Right angle clamps	-	507
Swivel clamps	-	193
Base plates	-	49
Corrugated sheets	5,50x6,4 m	1
Isulation	90x90x5 cm	172
	90x110x10 cm	6
	90x90x10 cm	3
Omega connectors	-	60
Eyelets with screws	-	90
Tie rods ϕ 22 mm	Length 1,5 m	20
Steel plates	75x75x6 mm	40
Polyester bands	17 m	2
Window fixtures	Porta 2,10x0,80	1
	Porta 2,10x0,80	3
	Anta doccia 2x0,7	3

REFECTORY		
Typology	Dimensions	Quantity (n.)
Wooden boards	12x2,5x75 cm	1
	12x2,5x320 cm	1
	12x2,5x405 cm	2
	12x2,5x500 cm	7
	15x2,5x30 cm	14

	15x2,5x100 cm	37
	15x2,5x130 cm	29
	15x2,5x135 cm	20
	15x2,5x150 cm	8
	15x2,5x160 cm	20
	15x2,5x210 cm	5
	15x2,5x325 cm	14
	15x2,5x380 cm	168
	15x2,5x395 cm	40
	15x2,5x460 cm	46
	10x5x300 cm	6
	15x5x75 cm	1
	15x5x320 cm	1
	15x5x405 cm	2
	20x5x200 cm	276
	20x5x210 cm	92
Wooden components	5x5x400 cm	40
	5x5x450 cm	16
Wooden beams	14x18x140 cm	24
	20x20x110 cm	1
	20x20x170 cm	4
	20x20x300 cm	6
HEA 200	Length 3,75 m	6
UPN 180	Length 4,00 m	12
Double UPN 180	Length 4,50 m	12
Polyester bands	Length 0,8 m	10
	Length 1,2 m	8
	Length 3,5 m	48
L brackets	100x100x50x6 mm	16
	100x50x50x6 mm	16
	3000x50x50x6 mm	4
	200x200x200x6 mm	12
	150x150x150x6 mm	24
	400x80x80x6 mm	12
	190x80x80x6 mm	12
C brackets	100x150x50x6 mm	16
Steel plates	400x400x8 mm	6
Isulation	90x90x5 cm	230
	50x100x5 cm	320
Corrugated sheets	5,5x11 m	1
Window fixtures	Porta 2,10x0,90 m	1
	Finestra 1,50x1,60 m	2
Screw piles	8 cm (diametro)	6

OFFICES		
Typology	Dimensions	Quantity (n.)
Wooden boards	15x2,5x0,35 cm	48
	15x2,5x0,50 cm	40
	15x2,5x110 cm	8
	15x2,5x120 cm	12
	15x2,5x140 cm	14
	15x2,5x150 cm	40
	15x2,5x330 cm	142
	15x2,5x350 cm	46
	15x2,5x380 cm	35
	15x2,5x390 cm	47
	20x5x380 cm	68
Wooden components	5x5x180 cm	8
	5x5x190 cm	16
	5x5x330 cm	18
	5x5x340 cm	16
	5x5x370 cm	3
	5x5x380 cm	2
	5x5x395 cm	9
	10x10x375 cm	10
Wooden beams	10x20x110 cm	5
	10x20x330 cm	6
	10x15x330 cm	5
	14x18x160 cm	12
	14x18x310 cm	8
	20x20x370 cm	3
	20x20x380 cm	3
	20x20x395 cm	3
Corrugated sheets	5x7,5 m	1
L brackets	150x150x150x6 mm	42
U brackets	200x200x200x6 mm	9
Isulation	90x100x5 cm	266
Prefabricated reinforced concrete plinths	50x50x30 cm	9
Window fixtures	Porta 2,10x0,90 cm	1
	Finestra 1,20x0,90	2

APPENDIX_ G

EXAMPLE: PALAZZO BRANDANI

1 SISTEMI DI MESSA IN SICUREZZA

SISTEMA DI MESSA IN SICUREZZA	u.m.	quantità	%
Puntellatura in legname con impiego ritti, tavole, fasce, gattelli, croci e simili	mc	45,5	
Puntellatura costituita da elementi tubolari e giunti in acciaio, basette fisse e regolabili, spinotti etc.	cad	1648	
Cerchiatura e puntellatura con profilati in acciaio serie HEA, HEB, IPE, UPN	kg	23150	
Puntellatura di solai con puntelli in acciaio e legname, costituita da ritti, tavole, gattelli, croci e simili, per altezze fino a 4,00 m	mq	291	**LEGNO** 35,00% **ACCIAIO** 65,00%
Puntellatura di vano, di finestra, porte o simili, costituita a dopiia orditura con ritti, fasce, gattelli, croci e simili, con puntelli in legno	mq	131,4	

Le voci indicate sono coerenti con quanto descritto nel Prezzario della Regione Abruzzo 2013

INTERESSE DELL'IMPRESA AD ACQUISIRE LA PROPRIETA' DEI SISTEMI DI MESSA IN SICUREZZA	**NO**

DATA DI POSA IN OPERA	Anno	2010
DATA DI STIMA	Anno	2015
DURATA CANTIERE	N° mesi	18

				IL COMUNE MANTIENE LA PROPRIETA' DEI SISTEMI DI MESSA IN SICUREZZA	
				TRASPORTO	**FINE VITA**
SISTEMA DI MESSA IN SICUREZZA	**u.m.**	**quantità**	**%**	% Trasporto	% Fine Vita
Puntellatura in legname con impiego ritti, tavole, fasce, gattelli, croci e simili	mc	45,5		100,00%	100,00%
Puntellatura costituita da elementi tubolari e giunti in acciaio, basette fisse e regolabili, spinotti etc.	cad	1648		100,00%	100,00%
Cerchiatura e puntellatura con profilati in acciaio serie HEA, HEB, IPE, UPN	kg	23150		100,00%	100,00%
Puntellatura di solai con puntelli in acciaio e legname, costituita da ritti, tavole, gattelli, croci e simili, per altezze fino a 4,00 m	mq	291	**LEGNO**	**LEGNO**	**LEGNO**
			35,00%	35,00%	35,00%
			ACCIAIO	**ACCIAIO**	**ACCIAIO**
			65,00%	65,00%	65,00%
Puntellatura di vano, di finestra, porte o simili, costituita a dopiia orditura con ritti, fasce, gattelli, croci e simili, con puntelli in legno	mq	131,4		100,00%	100,00%

SCENARI DI FINE VITA	%
LEGNO	
Riciclo	80,00%
Recupero Energetico	20,00%
Stoccaggio	0,00%
Conferimento a discarica	0,00%
ACCIAIO	
Rivendita acciaio usato (riciclo)	100,00%
Stoccaggio	0,00%
FERRO	
Rivendita acciaio usato (riciclo)	0,00%
Stoccaggio	0,00%
POLIESTERE	
Stoccaggio	0,00%
Conferimento a discarica	0,00%

SISTEMA DI MESSA IN SICUREZZA	SMONTAGGIO						TRASPORTO					
	voce prezzario	u.m.	prezzo unitario	quantità	%	TOTALE COSTO SMONTAGGIO	voce prezzario	u.m.	prezzo unitario	perzzo unitario epurato dell'utile dell'impresa	quantità	TOTALE COSTO TRASPORTO
Puntellatura in legname con impiego ritti, tavole, fasce, gattelli, croci e simili	NP	mc	€ 416,87	45,5		€ 18.967,59	RA12- A/6-3 + ISTAT	mc	€ 2,62	€ 2,38	45,5	€ 108,37
Puntellatura costituita da elementi tubolari e giunti in acciaio, basette fisse e regolabili, spinotti etc.	RA13-P.02.12.40	cad	€ 8,78	1648		€ 14.469,44	RA12- A/6-3 + ISTAT	mc	€ 2,62	€ 2,38	16,48	€ 39,25
Cerchiatura e puntellatura con profilati in acciaio serie HEA, HEB, IPE, UPN	NP	kg	€ 4,78	23150		€ 110.657,00	RA12- A/6-3 + ISTAT	mc	€ 2,62	€ 2,38	3,0095	€ 7,17
Puntellatura di solai con puntelli in acciaio e legname, costituita da ritti, tavole, gattelli, croci e simili, per altezze fino a 4,00 m	NP	mq	€ 87,33	291	LEGNO 35,00% ACCIAIO 65,00%	€ 25.413,03	RA12- A/6-3 + ISTAT	mc	2,62	€ 2,38	LEGNO 10,185 ACCIAIO 2,83725	€ 24,26 / € 6,76
Puntellatura di vano, di finestra, porte o simili, costituita a dopiia orditura con ritti, fasce, gattelli, croci e simili, con puntelli in legno	NP	mq	€ 29,21	131,4		€ 3.838,19	RA12- A/6-3 + ISTAT	mc	€ 2,62	€ 2,38	13,14	€ 31,30
TOTALE						**€ 173.345,25**						**€ 217,11**

	TOTALE	U.M.
LEGNO	**68,825**	**mc**

SCENARI DI FINE VITA	%	eventuale voce prezzario	u.m.	prezzo unitario	quantità	costo	guadagno
RICICLO	80,00%	NP	Kg	€ 0,003	49554		€ 148,66
RECUPERO ENERGETICO	20,00%	NP			12388,5		€ 37,17
STOCCAGGIO	0,00%	NP	mq	€ 380,00	0	€ -	
CONFERIMENTO A DISCARICA	0,00%	RA13-E.01.210.20.o	Kg	€ 0,24	0	€ -	

	TOTALE	U.M.
ACCIAIO	**46143,7**	**Kg**

SCENARI DI FINE VITA	%	eventuale voce prezzario	u.m.	prezzo unitario	quantità	costo	guadagno
RIVENDITA ACCIAIO USATO (RICICLO)	100,00%	NP	Kg	€ 1,00	46143,7		€ 46.143,70
STOCCAGGIO	0,00%	NP	mq	€ 380,00	0	€ -	

	TOTALE	U.M.
FERRO	**0**	**Kg**

SCENARI DI FINE VITA	%	eventuale voce prezzario	u.m.	prezzo unitario	quantità	costo	guadagno
RIVENDITA FERRO USATO (RICICLO)	0,00%	NP	Kg	€ 0,10	0		€ -
STOCCAGGIO	0,00%	NP	mq	€ 380,00	0	€ -	

	TOTALE	U.M.
POLIESTERE	**0**	**ml**

SCENARI DI FINE VITA	%	eventuale voce prezzario	u.m.	prezzo unitario	quantità	costo	guadagno
STOCCAGGIO	0,00%	NP	mq	€ 380,00	0	€ 0,00	
CONFERIMENTO A DISCARICA	0,00%	RA13-E.01.210.20.q	Kg	€ 0,53	0	€ 0,00	

	COSTO	GUADAGNO
SCENARI DI FINE VITA- TOTALE	**€ 0,00**	**€ 46.329,53**

SISTEMA DI MESSA IN SICUREZZA	u.m.	quantità	%	u.m. (2)	quantità secondo u.m. (2)	TRASPORTO A DISCARICA/RIVENDITA								
						% trasporto	u.m.	quantità	Km	PEI non rinnovabile (MJ)	GWP effetto serra (kg CO2eq)	AP acidificazione (KgSO2eq)	EP eutrofizzazione (kgPO4eq)	POCP Smog estivo (KgC2H4eq)
Puntellatura in legname con impiego ritti, tavole, fasce, gattelli, croci e simili	mc	45,5		mc	45,5	100,00%	t	40,95	100	6.142,5000	450,4500	4,0541	0,6552	0,7781
Puntellatura costituita da elementi tubolari e giunti in acciaio, basette fisse e regolabili, spinotti etc.	cad	1648		Kg	8240	100,00%	t	8,24	100	1.236,0000	90,6400	0,8158	0,1318	0,1566
Cerchiatura e puntellatura con profilati in acciaio serie HEA, HEB, IPE, UPN	kg	23150		Kg	23150	100,00%	t	23,15	100	3.472,5000	254,6500	2,2919	0,3704	0,4399
Puntellatura di solai con puntelli in acciaio e legname, costituita da ritti, tavole, gattelli, croci e simili, per altezze fino a 4,00 m	mq	291	LEGNO 35,00%	mc	10,185	LEGNO 35,00%	t	LEGNO 1,12289625	100	168,4344	12,3519	0,1112	0,0180	0,0213
			ACCIAIO 65,00%	Kg	14753,7	ACCIAIO 65,00%		ACCIAIO 6,23343825	100	935,0157	68,5678	0,6171	0,0997	0,1184
Puntellatura di vano, di finestra, porte o simili, costituita a dopiia orditura con ritti, fasce, gattelli, croci e simili, con puntelli in legno	mq	131,4		mc	13,14	100,00%	t	11,826	100	1.773,9000	130,0860	1,1708	0,1892	0,2247
TOTALE										**13.728,3502**	**1.006,7457**	**9,0607**	**1,4644**	**1,7389**

	TOTALE	U.M.
LEGNO	**53,16901369**	**mc**

SCENARI DI FINE VITA	%
RICICLO	80,00%
RECUPERO ENERGETICO	20,00%
STOCCAGGIO	0,00%
CONFERIMENTO A DISCARICA	0,00%

	TOTALE	U.M.
ACCIAIO	**46143,7**	**Kg**

SCENARI DI FINE VITA	%
RIVENDITA ACCIAIO USATO (RICICLO)	100,00%
STOCCAGGIO	0,00%

	TOTALE	U.M.
FERRO	**0**	**Kg**

SCENARI DI FINE VITA	%
RIVENDITA FERRO USATO (RICICLO)	0,00%
STOCCAGGIO	0,00%

	TOTALE	U.M.
POLIESTERE	**0**	**ml**

SCENARI DI FINE VITA	%
STOCCAGGIO	0,00%
CONFERIMENTO A DISCARICA	0,00%

SISTEMA DI MESSA IN SICUREZZA	u.m.	quantità	%	u.m. (2)	quantità secondo u.m. (2)	FINE VITA							
						% Fine Vita	Quantità secondo u.m. (2)	PEI non rinnovabile (MJ)	GWP effetto serra (kg CO2eq)	AP acidificazione (KgSO2eq)	EP eutrofizzazione (kgPO4eq)	POCP Smog estivo (KgC2H4eq)	Potere calorifico (MJ)
Puntellatura in legname con impiego ritti, tavole, fasce, gattelli, croci e simili	mc	45,5		mc	45,5	100,00%	45,5	9.698,3250	0,0000	5,8923	0,6529	4,9368	79.852,5000
Puntellatura costituita da elementi tubolari e giunti in acciaio, basette fisse e regolabili, spinotti etc.	cad	1648		Kg	8240	100,00%	8240	91.817,1429	6.503,7143	19,5111	1,6068	3,1371	-
Cerchiatura e puntellatura con profilati in acciaio serie HEA, HEB, IPE, UPN	kg	23150		Kg	23150	100,00%	23150	257.957,1429	18.271,9643	54,8159	4,5143	8,8135	-
Puntellatura di solai con puntelli in acciaio e legname, costituita da ritti, tavole, gattelli, croci e simili, per altezze fino a 4,00 m	mq	291	LEGNO 35,00%	mc	10,185	LEGNO 35,00%	3,56475	759,8265	0,0000	0,4616	0,0512	0,3868	6.256,1363
			ACCIAIO 65,00%	Kg	14753,7	ACCIAIO 65,00%	9589,905	106.858,9414	7.569,1750	22,7075	1,8700	3,6510	-
Puntellatura di vano, di finestra, porte o simili, costituita a dopiia orditura con ritti, fasce, gattelli, croci e simili, con puntelli in legno	mq	131,4		mc	13,14	100,00%	13,14	2.800,7910	0,0000	1,7016	0,1886	1,4257	23.060,7000
TOTALE								**469.892,1696**	**32.344,8536**	**105,0901**	**8,8837**	**22,3509**	**109.169,3363**

	TOTALE	U.M.
LEGNO	**53,16901369**	**mc**

SCENARI DI FINE VITA	%
RICICLO	80,00%
RECUPERO ENERGETICO	20,00%
STOCCAGGIO	0,00%
CONFERIMENTO A DISCARICA	0,00%

	TOTALE	U.M.
ACCIAIO	**46143,7**	**Kg**

SCENARI DI FINE VITA	%
RIVENDITA ACCIAIO USATO (RICICLO)	100,00%
STOCCAGGIO	0,00%

	TOTALE	U.M.
FERRO	**0**	**Kg**

SCENARI DI FINE VITA	%
RIVENDITA FERRO USATO (RICICLO)	0,00%
STOCCAGGIO	0,00%

	TOTALE	U.M.
POLIESTERE	**0**	**ml**

SCENARI DI FINE VITA	%
STOCCAGGIO	0,00%
CONFERIMENTO A DISCARICA	0,00%

INTERESSE DELL'IMPRESA AD ACQUISIRE LA PROPRIETA' DEI SISTEMI DI MESSA IN SICUREZZA	NO

DATA DI POSA IN OPERA	Anno	2010
DATA DI STIMA	Anno	2015
DURATA CANTIERE	N° mesi	18

VALUTAZIONE ECONOMICA

IL COMUNE MANTIENE LA PROPRIETA' DEI SISTEMI DI MESSA IN SICUREZZA

	SMONTAGGIO		TRASPORTO	FINE VITA		TOTALE		Δ€
	COSTO	GUADAGNO	COSTO	COSTO	GUADAGNO	COSTO	GUADAGNO	
COMUNE	€ 173.345,25		€ 217,11	€ 0,00	€ 46.329,53	€ 173.562,36	€ 46.329,53	-€ 127.232,83
IMPRESA		€ 15.758,66				€ 0,00	€ 15.758,66	€ 15.758,66

L'IMPRESA ACQUISISCE LA PROPRIETA' DEI SISTEMI DI MESSA IN SICUREZZA

	VALORE RESIDUO SISTEMI DI MESSA IN SICUREZZA		SMONTAGGIO	RECUPERO ENDOGENO		TRASPORTO	RECUPERO ESOGENO		FINE VITA		TOTALE		Δ€
	COSTO	GUADAGNO	COSTO	COSTO	GUADAGNO	COSTO	COSTO	GUADAGNO	COSTO	GUADAGNO	COSTO	GUADAGNO	
COMUNE		€ 0,00									0	0	€ 0,00
IMPRESA	€ 0,00		€ 0,00		€ 0,00	€ 0,00		€ 0,00	€ -	€ -	0	0	€ 0,00

VALUTAZIONE AMBIENTALE

IL COMUNE MANTIENE LA PROPRIETA' DEI SISTEMI DI MESSA IN SICUREZZA

ECOBILANCIO	U.M.	TRASPORTO	FINE VITA	TOTALE
PEI non rinnovabile	MJ	13.728,3502	469.892,1696	483.620,5198
GWP Effetto serra	kgCO2eq	1.006,7457	32.344,8536	33.351,5993
AP Acidificazione	KgSO2eq	9,0607	105,0901	114,1508
EP Eutrofizzazione	KgPO4eq	1,4644	8,8837	10,3481
POCP Smog estivo	kgC2H4eq	1,7389	22,3509	24,0898
Potere calorifico	MJ	-	109.169,3363	109.169,3363

L'IMPRESA ACQUISISCE LA PROPRIETA' DEI SISTEMI DI MESSA IN SICUREZZA

ECOBILANCIO	U.M.	RECUPERO ENDOGENO		TRASPORTO	RECUPERO ESOGENO	FINE VITA	TOTALE
		PERMANENTE	TEMPORANEO				
PEI non rinnovabile	MJ	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
GWP Effetto serra	kgCO2eq	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
AP Acidificazione	KgSO2eq	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
EP Eutrofizzazione	KgPO4eq	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
POCP Smog estivo	kgC2H4eq	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Potere calorifico	MJ	-	-	-	-	0,0000	0,0000

INTERESSE DELL'IMPRESA AD ACQUISIRE LA PROPRIETA' DEI SISTEMI DI MESSA IN SICUREZZA	**SI**

DATA DI POSA IN OPERA	Anno	2010
DATA DI STIMA	Anno	2015
DURATA CANTIERE	N° mesi	18

SISTEMA DI MESSA IN SICUREZZA	u.m.	quantità	%	L'IMPRESA ACQUISISCE LA PROPRIETA' DEI SISTEMI DI MESSA IN SICUREZZA – RECUPERO ENDOGENO: % Recupero Endogeno	RECUPERO ENDOGENO: % Riutilizzo PERMANENTE	RECUPERO ENDOGENO: % Riutilizzo TEMPORANEO	TRASPORTO: % Trasporto	RECUPERO ESOGENO: % Recupero Esogeno	FINE VITA: % Fine Vita
Puntellatura in legname con impiego ritti, tavole, fasce, gattelli, croci e simili	mc	45,5		30,00%	0,00%	30,00%	70,00%	50,00%	20,00%
Puntellatura costituita da elementi tubolari e giunti in acciaio, basette fisse e regolabili, spinotti etc.	cad	1648		80,00%	0,00%	80,00%	20,00%	20,00%	0,00%
Cerchiatura e puntellatura con profilati in acciaio serie HEA, HEB, IPE, UPN	kg	23150		10,00%	5,00%	5,00%	90,00%	60,00%	30,00%
Puntellatura di solai con puntelli in acciaio e legname, costituita da ritti, tavole, gattelli, croci e simili, per altezze fino a 4,00 m	mq	291	**LEGNO**	**LEGNO**	**LEGNO**	**LEGNO**	**LEGNO**	**LEGNO**	**LEGNO**
			35,00%	10,00%	0,00%	10,00%	25,00%	15,00%	10,00%
			ACCIAIO	**ACCIAIO**	**ACCIAIO**	**ACCIAIO**	**ACCIAIO**	**ACCIAIO**	**ACCIAIO**
			65,00%	10,00%	5,00%	5,00%	55,00%	40,00%	15,00%
Puntellatura di vano, di finestra, porte o simili, costituita a doppia orditura con ritti, fasce, gattelli, croci e simili, con puntelli in legno	mq	131,4		30,00%	0,00%	30,00%	70,00%	50,00%	20,00%

SCENARI DI FINE VITA	%
LEGNO	
Riciclo	50,00%
Recupero Energetico	50,00%
Stoccaggio	0,00%
Conferimento a discarica	0,00%
ACCIAIO	
Rivendita acciaio usato (riciclo)	100,00%
Stoccaggio	0,00%
FERRO	
Rivendita acciaio usato (riciclo)	0,00%
Stoccaggio	0,00%
POLIESTERE	
Stoccaggio	0,00%
Conferimento a discarica	0,00%

SISTEMA DI MESSA IN SICUREZZA	u.m.	quantità	%	PREZZO DI ACQUISTO DELL'IMPRESA DEL MATERIALE	SMONTAGGIO voce prezzario	prezzo unitario	prezzo unitario epurato dell'utile dell'impresa	TOTALE COSTO SMONTAGGIO	RECUPERO ENDOGENO % Rec. End.	Modalità di riutilizzo PERMANENTE	TOTALE GUADAGNO	Modalità di riutilizzo TEMPORANEO
Puntellatura in legname con impiego ritti, tavole, fasce, gattelli, croci e simili	mc	45,5		€ 3.869,27	NP	€ 416,87	€ 378,97	€ 17.243,26	30,00%	0,00%	€ 0,00	30,00%
Puntellatura costituita da elementi tubolari e giunti in acciaio, basette fisse e regolabili, spinotti etc.	cad	1648		€ 6.242,81	RA13-P.02.12.40	€ 8,78	€ 7,98	€ 13.154,04	80,00%	0,00%	€ 0,00	80,00%
Cerchiatura e puntellatura con profilati in acciaio serie HEA, HEB, IPE, UPN	kg	23150		€ 2,07	NP	€ 4,78	€ 4,35	€ 100.597,27	10,00%	5,00%	€ 4.190,43	5,00%
Cerchiature di pilastri e spigoli realizzati attraverso l'uso di fasce a cricchetto da 75 mm in poliestere per una lunghezza fino a 5,00 ml.	cad	0		€ 0,00	NP	€ 68,82	€ 62,56	€ 0,00	0,00%	0,00%	€ 0,00	0,00%
Cerchiature di pilastri e spigoli realizzati attraverso l'uso di fasce a cricchetto da 75 mm in poliestere per una lunghezza da 5,00 fino a 10,00 ml.	cad	0		€ 0,00	NP	€ 83,05	€ 75,50	€ 0,00	0,00%	0,00%	€ 0,00	0,00%
Cerchiature di pilastri e spigoli realizzati attraverso l'uso di fasce a cricchetto da 75 mm in poliestere per una lunghezza da 10,00 fino a 15,00 ml.	cad	0		€ 0,00	NP	€ 96,96	€ 88,15	€ 0,00	0,00%	0,00%	€ 0,00	0,00%
Puntellatura di solai con puntelli in acciaio e legname, costituita da ritti, tavole, gattelli, croci e simili, per altezze fino a 4,00 m	mq	291	LEGNO 35,00% ACCIAIO 65,00%	€ 8.557,45	NP	€ 87,33	€ 79,39	€ 23.102,75	LEGNO 10,00% ACCIAIO 10,00%	LEGNO 0,00% ACCIAIO 5,00%	€ 0,00 € 1.711,49	LEGNO 10,00% ACCIAIO 5,00%
Puntellatura di solai con puntelli in acciaio e legname, costituita da ritti, tavole, gattelli, croci e simili, per altezze da 4,00 m fino a 7,00 m	mq	0	LEGNO 0,00% ACCIAIO 0,00%	€ 0,00	NP	€ 13,90	€ 12,64	€ 0,00	LEGNO 0,00% ACCIAIO 0,00%	LEGNO 0,00% ACCIAIO 0,00%	€ 0,00 € 0,00	LEGNO 0,00% ACCIAIO 0,00%
Puntellatura di travi, costituita da ritti, tavole, fasce, gattelli, croci e simili, per altezze fino a 4,00 m	m	0	LEGNO 0,00% ACCIAIO 0,00%	€ 0,00	NP	€ 43,67	€ 378,97	€ 0,00	LEGNO 0,00% ACCIAIO 0,00%	LEGNO 0,00% ACCIAIO 0,00%	€ 0,00 € 0,00	LEGNO 0,00% ACCIAIO 0,00%
Puntellatura di travi, costituita da ritti, tavole, fasce, gattelli, croci e simili, per altezze da 4,00 m a 7,00 m	m	0	LEGNO 0,00% ACCIAIO 0,00%	€ 0,00	NP	€ 6,96	€ 6,33	€ 0,00	LEGNO 0,00% ACCIAIO 0,00%	LEGNO 0,00% ACCIAIO 0,00%	€ 0,00 € 0,00	LEGNO 0,00% ACCIAIO 0,00%
Puntellatura di vano, di finestra, porte o simili, costituita a dopiia orditura con ritti, fasce, gattelli, croci e simili, con puntelli in legno	mq	131,4		€ 1.176,58	NP	€ 29,21	€ 26,55	€ 3.489,27	30,00%	0,00%	€ 0,00	30,00%
Puntellatura di vano, di finestra, porte o simili, costituita a dopiia orditura con ritti, fasce, gattelli, croci e simili, con puntelli in ferro	mq	0		€ 0,00	NP	€ 17,39	€ 15,81	€ 0,00	0,00%	0,00%	€ 0,00	0,00%
Funi in acciaio zincato (trefoli) del diametro di 16 mm per controventatura di piano e per ancoraggio e irrigidimento di elementi in legno e/o ferro	m	0		€ 0,00	NP	€ 6,96	€ 6,33	€ 0,00	0,00%	0,00%	€ 0,00	0,00%
Struttura complessa in acciaio e legno per confinamento, contenimento e tirantatura posizionata su facciate o setti murari contrapposti, costituita da orditura principale orizzontale in correnti metallici e orditura secondaria verticale in travi reticolari in legno, con palanche lignee spessorate per raggiungere la complanarità della facciata, per altezze superiori a 3 m dal piano campagna.	mq	0	LEGNO 0,00% ACCIAIO 0,00%	€ 0,00	NP	€ 81,43	€ 74,03	€ 0,00	LEGNO 0,00% ACCIAIO 0,00%	LEGNO 0,00% ACCIAIO 0,00%	€ 0,00 € 0,00	LEGNO 0,00% ACCIAIO 0,00%
Struttura complessa in acciaio e legno per confinamento, contenimento e tirantatura posizionata su facciate o setti murari contrapposti, costituita da orditura principale orizzontale in correnti metallici e orditura secondaria verticale in travi reticolari in legno, con palanche lignee spessorate per raggiungere la complanarità della facciata, per altezze inferiori a 3 m dal piano campagna.	mq	0	LEGNO 0,00% ACCIAIO 0,00%	€ 0,00	NP	€ 84,79	€ 77,08	€ 0,00	LEGNO 0,00% ACCIAIO 0,00%	LEGNO 0,00% ACCIAIO 0,00%	€ 0,00 € 0,00	LEGNO 0,00% ACCIAIO 0,00%
TOTALE				€ 19.848,18				€ 157.586,59			€ 5.901,92	

RECUPERO ENDOGENO Totale quantità per riutilizzo temporaneo	Tipo di riutilizzo temporaneo	u.m	quantità	TOTALE GUADAGNO	TRASPORTO A DISCARICA/RIVENDITA % Trasporto	voce prezzario	u.m.	prezzo unitario	perzzo unitario epurato dell'utile dell'impresa	quantità	TOTALE COSTO TRASPORTO	RECUPERO ESOGENO % Rec. Esog.	TOTALE GUADAGNO	FINE VITA % Fine Vita
LEGNO (mc)	Ponteggio o incastellatura realizzato con elementi a telaio sovrapponibili	mq	0	€ 0,00	70,00%	RA12- A/6-3 + ISTAT	mc	€ 2,62	€ 2,38	31,85	€ 75,86	50,00%	€ 7.738,55	20,00%
20,50	Ponteggio metallico fisso costituito da elementi tubolari e giunti in acciaio, pianali in legno o metallo	cad	0	€ 0,00	20,00%	RA12- A/6-3 + ISTAT	mc	€ 2,62	€ 2,38	3,296	€ 7,85	20,00%	€ 1.747,99	0,00%
	Ponteggio completo con l'impiego di tubi e giunti e/o manicotti spinottati.	mq	85	€ 3.169,38	90,00%	RA12- A/6-3 + ISTAT	mc	€ 2,62	€ 2,38	2,70855	€ 6,45	60,00%	€ 50.285,18	30,00%
	Recinzione provvisionale di cantiere con con lamiera ondulata 3/10 su paletti di legno	mq	0	€ 0,00	0,00%	RA12- A/6-3 + ISTAT	mc	€ 2,62	€ 2,38	0	€ 0,00	0,00%	€ 0,00	0,00%
TUBI E GIUNTI (cad)	Recinzione provvisionale di cantiere con rete metallica zincata su tubi da ponteggio	mq	0	€ 0,00	0,00%	RA12- A/6-3 + ISTAT	mc	€ 2,62	€ 2,38	0	€ 0,00	0,00%	€ 0,00	0,00%
1318,4	Recinzione cieca provvisionale di cantiere, contavolame e travi di legno	mq	0	€ 0,00	0,00%	RA12- A/6-3 + ISTAT	mc	€ 2,62	€ 2,38	0	€ 0,00	0,00%	€ 0,00	0,00%
	Recinzione cieca provvisionale di cantiere, con tavolame in legno e elementi tubolari metallici.	mq	0	€ 0,00	LEGNO 25,00% ACCIAIO 55,00%	RA12- A/6-3 + ISTAT	mc	2,62	€ 2,38	LEGNO 2,54625 ACCIAIO 1,5604875	€ 6,06 € 3,72	LEGNO 15,00% ACCIAIO 40,00%	€ 5.134,47 € 13.691,92	10,00% 15,00%
PROFILI IN ACCIAIO (Kg)	Tettoie per la protezione dall'investimento di oggetti caduti dall'alto con struttura con tubolari da ponteggio e lamiera grecata	mq	0	€ 0,00	LEGNO 0,00% ACCIAIO 0,00%	RA12- A/6-3 + ISTAT	mc	2,62	€ 2,38	LEGNO 0 ACCIAIO 0	€ 0,00 € 0,00	LEGNO 0,00% ACCIAIO 0,00%	€ 0,00 € 0,00	0,00% 0,00%
8884,40	Prefabbricato 450x240x240	cad	4	€ 14.661,34	LEGNO 0,00% ACCIAIO 0,00%	RA12- A/6-3 + ISTAT	mc	2,62	€ 2,38	LEGNO 0 ACCIAIO 0	€ 0,00 € 0,00	LEGNO 0,00% ACCIAIO 0,00%	€ 0,00 € 0,00	0,00% 0,00%
	Prefabbricato 450x240x270	cad	0	€ 0,00	LEGNO 0,00% ACCIAIO 0,00%	RA12- A/6-3 + ISTAT	mc	2,62	€ 2,38	LEGNO 0 ACCIAIO 0	€ 0,00 € 0,00	LEGNO 0,00% ACCIAIO 0,00%	€ 0,00 € 0,00	0,00% 0,00%
FERRO (Kg)	Prefabbricato 540x240x240	cad	0	€ 0,00	70,00%	RA12- A/6-3 + ISTAT	mc	€ 2,62	€ 2,38	9,198	€ 21,91	50,00%	€ 2.353,16	20,00%
0,00	Prefabbricato 540x240x270	cad	0	€ 0,00	0,00%	RA12- A/6-3 + ISTAT	mc	€ 2,62	€ 2,38	0	€ 0,00	0,00%	€ 0,00	0,00%
	Prefabbricato 640x240x240	cad	0	€ 0,00	0,00%	RA12- A/6-3 + ISTAT	mc	€ 2,62	€ 2,38	0	€ 0,00	0,00%	€ 0,00	0,00%
	Prefabbricato 640x240x270	cad	0	€ 0,00	LEGNO 0,00%	RA12- A/6-3 + ISTAT	mc	2,62	€ 2,38	LEGNO 0	€ 0,00	LEGNO 0,00%	€ 0,00	0,00%
POLIESTERE (ml)	Prefabbricato 710x240x240	cad	0	€ 0,00	ACCIAIO 0,00%					ACCIAIO 0	€ 0,00	ACCIAIO 0,00%	€ 0,00	0,00%
0,00	Prefabbricato 710x240x270	cad	0	€ 0,00	LEGNO 0,00%	RA12- A/6-3 + ISTAT	mc	2,62	€ 2,38	LEGNO 0	€ 0,00	LEGNO 0,00%	€ 0,00	0,00%
	Altri servizi di cantiere		0	€ 0,00	ACCIAIO 0,00%					ACCIAIO 0	€ 0,00	ACCIAIO 0,00%	€ 0,00	0,00%
				€ 17.830,72							€ 121,85		€ 80.951,27	

	TOTALE	U.M.
LEGNO	8,464225	mc

SCENARI DI FINE VITA	%	u.m.	prezzo unitario	eventuale voce prezzario	quantità	costo	guadagno
RICICLO	50,00%	Kg	€ 0,00	NP	3808,90125		€ 11,43
RECUPERO ENERGETICO	50,00%			NP	3808,90125		€ 11,43
STOCCAGGIO	0,00%	mq	€ 380,00	NP	0	€ -	
CONFERIMENTO A DISCARICA	0,00%	Kg	€ 0,24	RA13- E.01.210.20.o	0	€ -	

	TOTALE	U.M.
ACCIAIO	10349,7	Kg

SCENARI DI FINE VITA	%	u.m.	prezzo unitario	eventuale voce prezzario	quantità	costo	guadagno
RIVENDITA ACCIAIO USATO (RICICLO)	100,00%	Kg	€ 1,00	NP	10349,7		€ 10.349,70
STOCCAGGIO	0,00%	mq	€ 380,00	NP	0	€ -	

	TOTALE	U.M.
FERRO	0	Kg

SCENARI DI FINE VITA	%	u.m.	prezzo unitario	eventuale voce prezzario	quantità	costo	guadagno
RIVENDITA FERRO USATO (RICICLO)	0,00%	Kg	€ 0,10	NP	0		€ -
STOCCAGGIO	0,00%	mq	€ 380,00	NP	0	€ -	

	TOTALE	U.M.
POLIESTERE	0	ml

SCENARI DI FINE VITA	%	u.m.	prezzo unitario	eventuale voce prezzario	quantità	costo	guadagno
STOCCAGGIO	0,00%	mq	€ 380,00	NP	0	€ -	
CONFERIMENTO A DISCARICA	0,00%	Kg	€ 0,53	RA13- E.01.210.20.q	0	0	

	COSTO	GUADAGNO
SCENARI DI FINE VITA- TOTALE	**€ -**	**€ 10.372,55**

SISTEMA DI MESSA IN SICUREZZA	u.m.	quantità	%	u.m. (2)	quantità secondo u.m. (2)	RECUPERO ENDOGENO														
						% Rec. End.	Modalità di riutilizzo PERMANENTE	Quantità secondo u.m. (2)	PEI non rinnovabile (MJ)	GWP effetto serra (kg CO2eq)	AP acidificazione (KgSO2eq)	EP eutrofizzazione (kgPO4eq)	POCP Smog estivo (KgC2H4eq)	Modalità di riutilizzo TEMPORANEO	Quantità secondo u.m. (2)	PEI non rinnovabile (MJ)	GWP effetto serra (kg CO2eq)	AP acidificazione (KgSO2eq)	EP eutrofizzazione (kgPO4eq)	POCP Smog estivo (KgC2H4eq)
Puntellatura in legname con impiego ritti, tavole, fasce, gattelli, croci e simili	mc	45,5		mc	45,5	30,00%	0,00%	0	0	0	0	0	0	30,00%	13,65	3117,31875	0	1,8939375	0,20986875	1,5868125
Puntellatura costituita da elementi tubolari e giunti in acciaio, basette fisse e regolabili, spinotti etc.	cad	1648		Kg	8240	80,00%	0,00%	0	0	0	0	0	0	80,00%	6592	36161,82857	2561,462857	7,684388571	0,632832	1,235529143
Cerchiatura e puntellatura con profilati in acciaio serie HEA, HEB, IPE, UPN	kg	23150		Kg	23150	10,00%	5,00%	1157,5	5952,857143	421,6607143	1,264982143	0,104175	0,203389286	5,00%	1157,5	6349,714286	449,7714286	1,349314286	0,11112	0,216948571
Puntellatura di solai con puntelli in acciaio e legname, costituita da ritti, tavole, gattelli, croci e simili, per altezze fino a 4,00 m	mq	291	LEGNO			LEGNO	LEGNO							LEGNO						
			35,00%	mc	10,185	10,00%	0,00%	0	0	0	0	0	0	10,00%	1,0185	232,5999375	0	0,141316875	0,015659438	0,118400625
			ACCIAIO			ACCIAIO	ACCIAIO							ACCIAIO						
			65,00%	Kg	14753,7	10,00%	5,00%	737,685	3793,808571	268,7281071	0,806184321	0,06639165	0,129621793	5,00%	737,685	4046,729143	286,6433143	0,859929943	0,07081776	0,138263246
Puntellatura di vano, di finestra, porte o simili, costituita a dopiia orditura con ritti, fasce, gattelli, croci e simili, con puntelli in legno	mq	131,4		mc	13,14	30,00%	0,00%	0	0	0	0	0	0	30,00%	3,942	900,25425	0	0,5469525	0,06060825	0,4582575
TOTALE									**9746,6657**	**690,3888**	**2,0712**	**0,1706**	**0,3330**			**50.808,4449**	**3.297,8776**	**12,4758**	**1,1009**	**3,7542**

SISTEMA DI MESSA IN SICUREZZA	u.m.	quantità	%	u.m. (2)	quantità secondo u.m. (2)	TRASPORTO /RIVENDITA % trasporto	u.m.	quantità	Km	PEI non rinnovabile (MJ)	GWP effetto serra (kg CO2eq)	AP acidificazione (KgSO2eq)	EP eutrofizzazione (kgPO4eq)	POCP Smog estivo (KgC2H4eq)	RECUPERO ESOGENO % Rec. Esog.	Quantità secondo u.m. (2)	PEI non rinnovabile (MJ)	GWP effetto serra (kg CO2eq)	AP acidificazione (KgSO2eq)	EP eutrofizzazione (kgPO4eq)	POCP Smog estivo (KgC2H4eq)
Puntellatura in legname con impiego ritti, tavole, fasce, gattelli, croci e simili	mc	45,5		mc	45,5	70,00%	t	28,665	10	429,975	31,5315	0,2837835	0,045864	0,0545	50,00%	22,75	0	0	0	0	0
Puntellatura costituita da elementi tubolari e giunti in acciaio, basette fisse e regolabili, spinotti etc.	cad	1648		Kg	8240	20,00%	t	1,648	10	24,72	1,8128	0,0163152	0,0026368	0,0031	20,00%	1648	8757,942857	620,3542857	1,861062857	0,153264	0,299229714
Cerchiatura e puntellatura con profilati in acciaio serie HEA, HEB, IPE, UPN	kg	23150		Kg	23150	90,00%	t	20,835	10	312,525	22,9185	0,2062665	0,033336	0,0396	60,00%	13890	73815,42857	5228,592857	15,68577857	1,29177	2,522027143
Puntellatura di solai con puntelli in acciaio e legname, costituita da ritti, tavole, gattelli, croci e simili, per altezze fino a 4,00 m	mq	291	**LEGNO** 35,00%	mc	10,185	**LEGNO** 25,00%	t	**LEGNO** 0,80206875	10	12,03103125	0,882275625	0,007940481	0,00128331	0,0015	**LEGNO** 15,00%	1,52775	0	0	0	0	0
			ACCIAIO 65,00%	Kg	14753,7	**ACCIAIO** 55,00%		**ACCIAIO** 5,27444775	10	79,11671625	5,801892525	0,052217033	0,008439116	0,0100	**ACCIAIO** 40,00%	5901,48	31362,15086	2221,485686	6,664457057	0,54883764	1,071540154
Puntellatura di vano, di finestra, porte o simili, costituita a dopiia orditura con ritti, fasce, gattelli, croci e simili, con puntelli in legno	mq	131,4		mc	13,14	70,00%	t	8,2782	10	124,173	9,10602	0,08195418	0,01324512	0,0157	50,00%	6,57	0	0	0	0	0
TOTALE										**982,5407**	**72,0530**	**0,6485**	**0,1048**	**0,1245**			**113935,5223**	**8070,4328**	**24,2113**	**1,99387164**	**3,8928**

SISTEMA DI MESSA IN SICUREZZA	u.m.	quantità	%	u.m. (2)	quantità secondo u.m. (2)	FINE VITA % Fine Vita	Quantità secondo u.m. (2)	PEI non rinnovabile (MJ)	GWP effetto serra (kg CO2eq)	AP acidificazione (KgSO2eq)	EP eutrofizzazione (kgPO4eq)	POCP Smog estivo (KgC2H4eq)	Potere calorifico (MJ)
Puntellatura in legname con impiego ritti, tavole, fasce, gattelli, croci e simili	mc	45,5		mc	45,5	20,00%	9,1	1212,290625	0	0,73653125	0,081615625	0,61709375	39926,2500
Puntellatura costituita da elementi tubolari e giunti in acciaio, basette fisse e regolabili, spinotti etc.	cad	1648		Kg	8240	0,00%	0	0	0	0	0	0	-
Cerchiatura e puntellatura con profilati in acciaio serie HEA, HEB, IPE, UPN	kg	23150		Kg	23150	30,00%	6945	77387,14286	5481,589286	16,44476786	1,354275	2,644060714	-
Puntellatura di solai con puntelli in acciaio e legname, costituita da ritti, tavole, gattelli, croci e simili, per altezze fino a 4,00 m	mq	291	LEGNO 35,00%	mc	10,185	LEGNO 10,00%	1,0185	135,6832969	0	0,082434844	0,009134672	0,069067031	4468,6688
			ACCIAIO 65,00%	Kg	14753,7	ACCIAIO 15,00%	2213,055	24659,75571	1746,732696	5,240198089	0,431545725	0,842541654	-
Puntellatura di vano, di finestra, porte o simili, costituita a dopiia orditura con ritti, fasce, gattelli, croci e simili, con puntelli in legno	mq	131,4		mc	13,14	20,00%	2,628	350,098875	0	0,21270375	0,023569875	0,17821125	11530,3500
TOTALE								**103.744,9714**	**7.228,3220**	**22,7166**	**1,9001**	**4,3510**	**55.925,2688**

	TOTALE	U.M.
LEGNO	7,468846875	mc

SCENARI DI FINE VITA	%
RICICLO	50,00%
RECUPERO ENERGETICO	50,00%
STOCCAGGIO	0,00%
CONFERIMENTO A DISCARICA	0,00%

	TOTALE	U.M.
ACCIAIO	10349,7	Kg

SCENARI DI FINE VITA	%
RIVENDITA ACCIAIO USATO (RICICLO)	100,00%
STOCCAGGIO	0,00%

	TOTALE	U.M.
FERRO	0	Kg

SCENARI DI FINE VITA	%
RIVENDITA FERRO USATO (RICICLO)	0,00%
STOCCAGGIO	0,00%

	TOTALE	U.M.
POLIESTERE	0	ml

SCENARI DI FINE VITA	%
STOCCAGGIO	0,00%
CONFERIMENTO A DISCARICA	0,00%

DATA DI STIMA	2015
DATA DI POSA IN OPERA	2010

SISTEMA DI MESSA IN SICUREZZA	VALORE A NUOVO UNITARIO			UTILI DI IMPRESA	SPESE GERALI	% MANODOPERA	MATERIALE	VITA UTILE	COEFFICIENTE DI DEGRADO	COEFFICIENTE DI DEPREZZAMENTO (difficoltà di riutilizzo per dimensioni, degrado nello smontaggio, etc.)	COEFICCIENTE DI PERCENTUALIZZAZIONE (il tecnico ha la possibilità di variare il prezzo unitario in funzione del sopralluogo in loco)	VALORE RESIDUO UNITARIO	
	voce prezzario	u.m	prezzo	10%	15%		costo	n.anni (1/4 della vita utile in condizioni standard)				u.m.	prezzo
Puntellatura in legname con impiego ritti, tavole, fasce, gattelli, croci e simili	P.02.10.20.a	mc	€ 759,84	€ 690,76	€ 600,66	43,37%	€ 340,16	10	0,500	0,500	100,00%	mc	€ 85,04
Puntellatura costituita da elementi tubolari e giunti in acciaio, basette fisse e regolabili, spinotti etc.	P.02.10.30.a	cad	€ 27,54	€ 25,04	€ 21,77	75,64%	€ 5,30	17,5	0,714	1,000	100,00%	cad	€ 3,79
Cerchiatura e puntellatura con profilati in acciaio serie HEA, HEB, IPE, UPN	P.02.10.50.a	kg	€ 8,36	€ 7,60	€ 6,61	45,22%	€ 3,62	17,5	0,714	0,800	100,00%	kg	€ 2,07
Cerchiature di pilastri e spigoli realizzati attraverso l'uso di fasce a cricchetto da 75 mm in poliestere per una lunghezza fino a 5,00 ml.	P.02.10.60.a	cad	€ 187,07	€ 170,06	€ 147,88	29,08%	€ 104,88	7,5	0,333	0,500	100,00%	cad	€ 17,48
Cerchiature di pilastri e spigoli realizzati attraverso l'uso di fasce a cricchetto da 75 mm in poliestere per una lunghezza da 5,00 fino a 10,00 ml.	P.02.10.70.a	cad	€ 239,26	€ 217,51	€ 189,14	27,44%	€ 137,24	7,5	0,333	0,500	100,00%	cad	€ 22,87
Cerchiature di pilastri e spigoli realizzati attraverso l'uso di fasce a cricchetto da 75 mm in poliestere per una lunghezza da 10,00 fino a 15,00 ml.	P.02.10.80.a	cad	€ 291,12	€ 264,65	€ 230,13	26,33%	€ 169,54	7,5	0,333	0,500	100,00%	cad	€ 28,26
Puntellatura di solai con puntelli in acciaio e legname, costituita da ritti, tavole, gattelli, croci e simili, per altezze fino a 4,00 m	P.02.10.100.a	mq	€ 217,83	€ 198,03	€ 172,20	31,69%	€ 117,63	7,5	0,333	0,750	100,00%	mq	€ 29,41
Puntellatura di solai con puntelli in acciaio e legname, costituita da ritti, tavole, gattelli, croci e simili, per altezze da 4,00 m fino a 7,00 m	P.02.10.100.d	mq	€ 43,59	€ 39,63	€ 34,46	25,21%	€ 25,77	13,75	0,636	0,750	100,00%	mq	€ 12,30
Puntellatura di travi, costituita da ritti, tavole, fasce, gattelli, croci e simili, per altezze fino a 4,00 m	P.02.10.110.a	m	€ 112,77	€ 102,52	€ 89,15	30,61%	€ 61,86	13,75	0,636	0,750	100,00%	m	€ 29,52
Puntellatura di travi, costituita da ritti, tavole, fasce, gattelli, croci e simili, per altezze da 4,00 m a 7,00 m	P.02.10.110.d	m	€ 20,44	€ 18,58	€ 16,16	26,91%	€ 11,81	13,75	0,636	0,750	100,00%	m	€ 22,87
Puntellatura di vano, di finestra, porte o simili, costituita a dopiia orditura con ritti, fasce, gattelli, croci e simili, con puntelli in legno	P.02.10.120.a	mq	€ 68,40	€ 62,18	€ 54,07	33,76%	€ 35,82	10	0,500	0,500	100,00%	mq	€ 8,95
Puntellatura di vano, di finestra, porte o simili, costituita a dopiia orditura con ritti, fasce, gattelli, croci e simili, con puntelli in ferro	P.02.10.120.e	mq	€ 104,13	€ 94,66	€ 82,32	13,20%	€ 71,45	10	0,500	0,500	100,00%	mq	€ 17,86
Funi in acciaio zincato (trefoli) del diametro di 16 mm per controventatura di piano e per ancoraggio e irrigidimento di elementi in legno e/o ferro	P.02.10.130.a	m	€ 20,77	€ 18,88	€ 16,42	26,48%	€ 12,07	17,5	0,714	0,500	100,00%	m	€ 4,31
Struttura complessa in acciaio e legno per confinamento, contenimento e tirantatura posizionata su facciate o setti murari contrapposti, costituita da orditura principale orizzontale in correnti metallici e orditura secondaria verticale in travi reticolari in legno, con palanche lignee spessorate per raggiungere la complanarità della facciata, per altezze superiori a 3 m dal piano campagna.	P.02.10.190.a	mq	€ 206,84	€ 188,04	€ 163,51	31,12%	€ 112,63	13,75	0,636	0,750	100,00%	mq	€ 53,75
Struttura complessa in acciaio e legno per confinamento, contenimento e tirantatura posizionata su facciate o setti murari contrapposti, costituita da orditura principale orizzontale in correnti metallici e orditura secondaria verticale in travi reticolari in legno, con palanche lignee spessorate per raggiungere la complanarità della facciata, per altezze inferiori a 3 m dal piano campagna.	P.02.10.190.b	mq	€ 137,63	€ 125,12	€ 108,80	48,70%	€ 55,81	13,75	0,636	0,750	100,00%	mq	€ 26,64

	n° mesi
DURATA CANTIERE	18

APPRESTAMENTI DI CANTIERE (VOCE SINTETICA)	APPRESTAMENTI DI CANTIERE	voce prezzario	u.m.	prezzo	% man	costo materiale	costo con incidenza dela durata del cantiere
Ponteggio o incastellatura realizzato con elementi a telaio sovrapponibili	Ponteggio o incastellatura realizzato con elementi a telaio sovrapponibili, valutato per mq di superficie asservita. Per il primo mese	P.04.10.30.a	mq	€ 6,80	64,71%	€ 1,90	€ 10,23
	Ponteggio o incastellatura realizzato con elementi a telaio sovrapponibili, valutato per mq di superficie asservita. Per ogni mese successivo	P.04.10.30.b	mq/30gg	€ 0,66	6,06%	€ 0,49	
Ponteggio metallico fisso costituito da elementi tubolari e giunti in acciaio, pianali in legno o metallo	Ponteggio metallico fisso costituito da elementi tubolari e giunti in acciaio realizzati in opera, compreso montaggio, smontaggio ad opera ultimata, pianali in legno o metallo o altro materiale idoneo, tavole fermapiede e parapetti, scale interne di collegamento tra painale e pianale, ancoraggi, l'adozione di tutti gli accorgimenti atti a tutelare l'incolumità degli operai e quanto altro occorre per dare la struttura installata nel rispetto della normativa vigente. Per i primi 6 mesi. Per giunto	P.04.10.40.a	cad	€ 15,91	64,49%	€ 4,47	€ 10,82
	Ponteggio metallico fisso costituito da elementi tubolari e giunti in acciaio realizzati in opera, compreso montaggio, smontaggio ad opera ultimata, pianali in legno o metallo o altro materiale idoneo, tavole fermapiede e parapetti, scale interne di collegamento tra painale e pianale, ancoraggi, l'adozione di tutti gli accorgimenti atti a tutelare l'incolumità degli operai e quanto altro occorre per dare la struttura installata nel rispetto della normativa vigente. Per ogni mese successivo. Per giunto	P.04.10.40.b	cad/30gg	€ 1,77	62,15%	€ 0,53	
Ponteggio completo con l'impiego di tubi e giunti e/o manicotti spinottati.	Ponteggio completo in opera con basette supporti agganci, tavolato, fermapiede e modulo scala, realizzato con l'impiego di tubi e giunti e/o manicotti spinottati. Per il primo mese.	P.04.10.140.a	mq	€ 34,84	50,07%	€ 13,75	€ 37,29
	Ponteggio completo in opera con basette supporti agganci, tavolato, fermapiede e modulo scala, realizzato con l'impiego di tubi e giunti e/o manicotti spinottati. Per ogni mese successivo.	P.04.10.140.b	mq/30gg	€ 3,47	49,53%	€ 1,38	
Recinzione provvisionale di cantiere con con lamiera ondulata 3/10 su paletti di legno	Recinzione provvisionale di cantiere di altezza non inferiore a m 2.00 con sostegni in paletti di legno o tubi da ponteggio. Completa delle necessarie controventature, segnalazioni luminose diurne e notturne e tabelle segnaletiche.Con lamiera ondulata 3/10 su paletti di legno: fornitura e posa	S.01.10.10.a1	mq	€ 19,43	65,31%	€ 5,33	€ 5,33
	Recinzione provvisionale di cantiere di altezza non inferiore a m 2.00 con sostegni in paletti di legno o tubi da ponteggio. Completa delle necessarie controventature, segnalazioni luminose diurne e notturne e tabelle segnaletiche.Con lamiera ondulata 3/10 su paletti di legno. Montaggio e nolo per i primi tre mesi	S.01.10.10.a2	mq	€ 12,99	61,05%	€ 4,00	€ 8,86
	Recinzione provvisionale di cantiere di altezza non inferiore a m 2.00 con sostegni in paletti di legno o tubi da ponteggio. Completa delle necessarie controventature, segnalazioni luminose diurne e notturne e tabelle segnaletiche.Con lamiera ondulata 3/10 su paletti di legno. Nolo per i mesi successivi.	S.01.10.10.a3	mq/30gg	€ 1,07	61,68%	€ 0,32	
Recinzione provvisionale di cantiere con rete metallica zincata su tubi da ponteggio	Recinzione provvisionale di cantiere di altezza non inferiore a m 2.00 con sostegni in paletti di legno o tubi da ponteggio. Completa delle necessarie controventature, segnalazioni luminose diurne e notturne e tabelle segnaletiche.Con rete metallica zincata su tubi da ponteggio: fornitura e posa	S.01.10.10.d1	mq	€ 20,76	63,68%	€ 5,96	€ 5,96
	Recinzione provvisionale di cantiere di altezza non inferiore a m 2.00 con sostegni in paletti di legno o tubi da ponteggio. Completa delle necessarie controventature, segnalazioni luminose diurne e notturne e tabelle segnaletiche.Con rete metallica zincata su tubi da ponteggio. Nolo per i primi 3 mesi	S.01.10.10.d2	mq	€ 11,88	66,75%	€ 3,12	€ 9,17
	Recinzione provvisionale di cantiere di altezza non inferiore a m 2.00 con sostegni in paletti di legno o tubi da ponteggio. Completa delle necessarie controventature, segnalazioni luminose diurne e notturne e tabelle segnaletiche.Con rete metallica zincata su tubi da ponteggio:Nolo per ogni mese successivo	S.01.10.10.d3	mq	€ 1,17	56,41%	€ 0,40	
Recinzione cieca provvisionale di cantiere, contavolame e travi di legno	Recinzione cieca provvisionale di cantiere, con tavolame in legno di altezza non inferiore a m 4.00 con sostegni in travi di abete o ponteggi metallici. Completa delle necessarie controventature, segnalazioni luminose diurne e notturne e tabelle segnaletiche. Con tavolame e travi di legno: fornitura e posa	S.01.10.20.a1	mq	19,71	66,92%	€ 5,15	€ 5,15
	Recinzione cieca provvisionale di cantiere, con tavolame in legno di altezza non inferiore a m 4.00 con sostegni in travi di abete o ponteggi metallici. Completa delle necessarie controventature, segnalazioni luminose diurne e notturne e tabelle segnaletiche. Con tavolame e travi di legno. Montaggio e nolo per i primi 3 mesi.	S.01.10.20.a2	mq	14,86	66,62%	€ 3,92	€ 8,90
	Recinzione cieca provvisionale di cantiere, con tavolame in legno di altezza non inferiore a m 4.00 con sostegni in travi di abete o ponteggi metallici. Completa delle necessarie controventature, segnalazioni luminose diurne e notturne e tabelle segnaletiche. Con tavolame e travi di legno. Nolo per ogni mese successivo.	S.01.10.20.a3	mq/30gg	1,25	66,40%	€ 0,33	
Recinzione cieca provvisionale di cantiere, con tavolame in legno e elementi tubolari metallici.	Recinzione cieca provvisionale di cantiere, con tavolame in legno di altezza non inferiore a m 4.00 con sostegni in travi di abete o ponteggi metallici. Completa delle necessarie controventature, segnalazioni luminose diurne e notturne e tabelle segnaletiche. Con tavolame in legno e elementi tubolari metallici: fornitura e posa	S.01.10.20.b1	mq	€ 23,18	66,39%	€ 6,16	€ 6,16
	Recinzione cieca provvisionale di cantiere, con tavolame in legno di altezza non inferiore a m 4.00 con sostegni in travi di abete o ponteggi metallici. Completa delle necessarie controventature, segnalazioni luminose diurne e notturne e tabelle segnaletiche. Con tavolame in legno e elementi tubolari metallici. Montaggio e nolo per i primi 3 mesi.	S.01.10.20.b2	mq	€ 15,60	63,46%	€ 4,51	€ 10,32
	Recinzione cieca provvisionale di cantiere, con tavolame in legno di altezza non inferiore a m 4.00 con sostegni in travi di abete o ponteggi metallici. Completa delle necessarie controventature, segnalazioni luminose diurne e notturne e tabelle segnaletiche. Con tavolame in legno e elementi tubolari metallici. Nolo per ogni mese successivo	S.01.10.20.b3	mq	€ 1,32	62,88%	€ 0,39	
Tettoie per la protezione dall'investimento di oggetti caduti dall'alto con struttura con tubolari da ponteggio e lamiera grecata	Tettoie per la protezione dall'investimento di oggetti caduti dall'alto fissate su struttura. Montaggio e nolo per il 1° mese. Con struttura con tubolari da ponteggio e lamiera grecata	S.02.10.10.b	mq	€ 165,10	66,58%	€ 43,62	€ 91,05
	Tettoie per la protezione dall'investimento di oggetti caduti dall'alto fissate su struttura. Nolo per i mesi successivi al primo, compreso gli oneri di manutenzione e tenuta in esercizio. Con struttura con tubolari da ponteggio e lamiera grecata	S.02.10.20.b	mq/30 gg	€ 9,03	60,91%	€ 2,79	
	Monoblocco prefabbricato per mense, spogliatoi, guardiole, uffici e locali infermeria: costituito da struttura in acciaio zincato a caldo e pannelli di tamponatura. Pareti in pannelli sandwich non inferiore a mm 40, con due lamiere d'acciaio zincate e preverniciate da 5/10 con poliuretano espanso autoestinguente, pavimenti in lastre di legno truciolare idrofugo rivestito in pvc, serramenti in alluminio anodizzato , impianto elettrico canalizzato rispondente al DM 37 del 22/01/2008, interruttore generale magnetotermico differenziale, tubazioni e scatole in materiale termoplastico autoestinguente con vaso, finestrino a vasistas e lavabo, completo di rubinetterie e scalda acqua, su basamento predisposto. Soluzione: con una finestra e portoncino esterno semivetrato (esclusi gli arredi). Trasporto in cantiere, posizionamento e rimozione, compreso allacciamenti alla rete dei servizi.(S.02.20.90)+Nolo mensile, compreso gli oneri di manutenzione e tenuta in esercizio (S.02.20.10)	S.02.20.90 +S.02.20.100					
Prefabbricato 450x240x240	dimensioni 450 x240 cm con altezza pari a 240 cm	S.02.20.90.a	cad	€ 421,20	20,00%	€ 266,37	€ 3.665,33
	dimensioni 450 x240 cm con altezza pari a 240 cm	S.02.20.100.a	cad	€ 247,10	3,33%	€ 188,83	
Prefabbricato 450x240x270	dimensioni 450 x240 cm con altezza pari a 270 cm	S.02.20.90.b	cad	€ 423,89	19,45%	€ 269,92	€ 3.835,34
	dimensioni 450 x240 cm con altezza pari a 270 cm	S.02.20.100.b	cad	€ 258,80	3,18%	€ 198,08	
Prefabbricato 540x240x240	dimensioni 540 x240 cm con altezza pari a 240 cm	S.02.20.90.c	cad	€ 431,28	19,12%	€ 275,75	€ 3.945,87
	dimensioni 540 x240 cm con altezza pari a 240 cm	S.02.20.100.c	cad	€ 266,18	3,10%	€ 203,90	
Prefabbricato 540x240x270	dimensioni 540 x240 cm con altezza pari a 270 cm	S.02.20.90.d	cad	€ 444,80	18,54%	€ 286,43	€ 4.149,08
	dimensioni 540 x240 cm con altezza pari a 270 cm	S.02.20.100.d	cad	€ 279,71	2,95%	€ 214,59	
Prefabbricato 640x240x240	dimensioni 640 x240 cm con altezza pari a 240 cm	S.02.20.90.e	cad	€ 463,13	17,80%	€ 300,94	€ 4.424,64
	dimensioni 640 x240 cm con altezza pari a 240 cm	S.02.20.100.e	cad	€ 298,03	2,76%	€ 229,09	
Prefabbricato 640x240x270	dimensioni 640 x240 cm con altezza pari a 270 cm	S.02.20.90.f	cad	€ 477,32	17,27%	€ 312,16	€ 4.637,53
	dimensioni 640 x240 cm con altezza pari a 270 cm	S.02.20.100.f	cad	€ 312,22	2,64%	€ 240,30	
Prefabbricato 710x240x240	dimensioni 710 x240 cm con altezza pari a 240 cm	S.02.20.90.g	cad	€ 500,28	16,48%	€ 330,30	€ 4.982,48
	dimensioni 710 x240 cm con altezza pari a 240 cm	S.02.20.100.g	cad	€ 335,19	2,46%	€ 258,45	
Prefabbricato 710x240x270	dimensioni 710 x240 cm con altezza pari a 270 cm	S.02.20.90.h	cad	€ 518,22	15,91%	€ 344,48	€ 5.252,04
	dimensioni 710 x240 cm con altezza pari a 270 cm	S.02.20.100.h	cad	€ 353,12	2,33%	€ 272,64	
Altri servizi di cantiere						€ 0,00	€ 0,00

INTERESSE DELL'IMPRESA AD ACQUISIRE LA PROPRIETA' DEI SISTEMI DI MESSA IN SICUREZZA	SI

DATA DI POSA IN OPERA	Anno	2010
DATA DI STIMA	Anno	2015
DURATA CANTIERE	N° mesi	18

VALUTAZIONE ECONOMICA

IL COMUNE MANTIENE LA PROPRIETA' DEI SISTEMI DI MESSA IN SICUREZZA

	SMONTAGGIO		TRASPORTO	FINE VITA		TOTALE		Δ€
	COSTO	GUADAGNO	COSTO	COSTO	GUADAGNO	COSTO	GUADAGNO	
COMUNE	€ 0,00		€ 0,00	€ 0,00	€ 0,00	€ 0,00	€ 0,00	€ 0,00
IMPRESA		€ 0,00				€ 0,00	€ 0,00	€ 0,00

L'IMPRESA ACQUISISCE LA PROPRIETA' DEI SISTEMI DI MESSA IN SICUREZZA

	VALORE RESIDUO SISTEMI DI MESSA IN SICUREZZA		SMONTAGGIO	RECUPERO ENDOGENO		TRASPORTO	RECUPERO ESOGENO		FINE VITA		TOTALE		Δ€
	COSTO	GUADAGNO	COSTO	COSTO	GUADAGNO	COSTO	COSTO	GUADAGNO	COSTO	GUADAGNO	COSTO	GUADAGNO	
COMUNE		€ 19.848,18									0	19848,18111	€ 19.848,18
IMPRESA	€ 19.848,18		€ 157.586,59		€ 23.732,64	€ 121,85		€ 80.951,27	€ -	€ 10.372,55	177556,6232	115056,4662	-€ 62.500,16

VALUTAZIONE AMBIENTALE

IL COMUNE MANTIENE LA PROPRIETA' DEI SISTEMI DI MESSA IN SICUREZZA

ECOBILANCIO	U.M.	TRASPORTO	FINE VITA	TOTALE
PEI non rinnovabile	MJ	0,0000	0,0000	0,0000
GWP Effetto serra	kgCO2eq	0,0000	0,0000	0,0000
AP Acidificazione	KgSO2eq	0,0000	0,0000	0,0000
EP Eutrofizzazione	KgPO4eq	0,0000	0,0000	0,0000
POCP Smog estivo	kgC2H4eq	0,0000	0,0000	0,0000
Potere calorifico	MJ	-	0,0000	0,0000

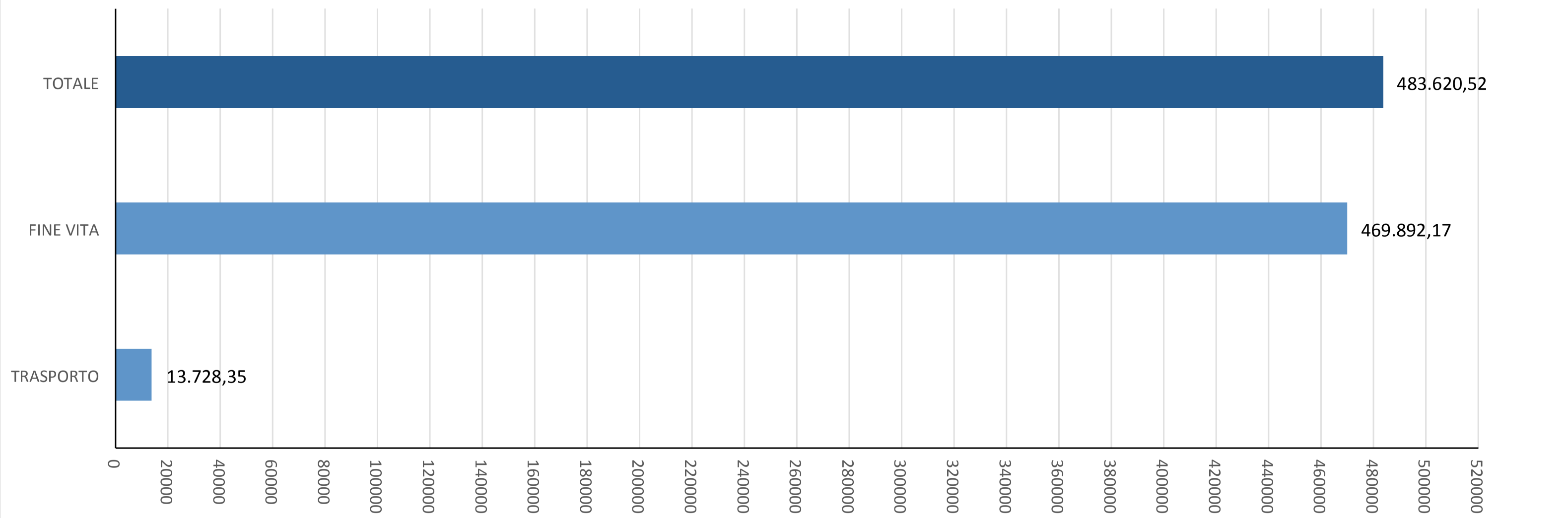
L'IMPRESA ACQUISISCE LA PROPRIETA' DEI SISTEMI DI MESSA IN SICUREZZA

ECOBILANCIO	U.M.	RECUPERO ENDOGENO		TRASPORTO	RECUPERO ESOGENO	FINE VITA	TOTALE
		PERMANENTE	TEMPORANEO				
PEI non rinnovabile	MJ	9.746,6657	50.808,4449	982,5407	113.935,5223	103.744,9714	279.218,1451
GWP Effetto serra	kgCO2eq	690,3888	3.297,8776	72,0530	8.070,4328	7.228,3220	19.359,0742
AP Acidificazione	KgSO2eq	2,0712	12,4758	0,6485	24,2113	22,7166	62,1234
EP Eutrofizzazione	KgPO4eq	0,1706	1,1009	0,1048	1,9939	1,9001	5,2703
POCP Smog estivo	kgC2H4eq	0,3330	3,7542	0,1245	3,8928	4,3510	12,4554
Potere calorifico	MJ	-	-	-	-	55.925,2688	55.925,2688

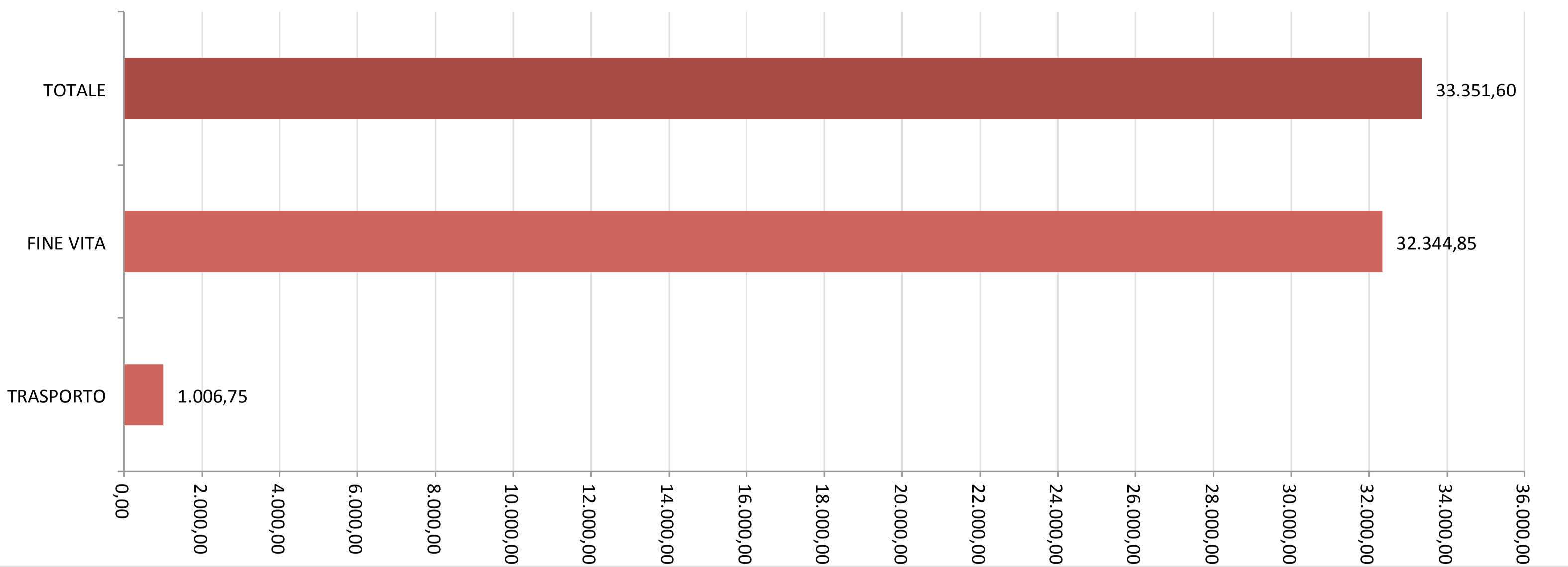
IL COMUNE MANTIENE LA PROPRIETA' DEI SISTEMI DI MESSA IN SICUREZZA

	U.M.	TRASPORTO	FINE VITA	TOTALE
PEI non rinnovabile	MJ	13.728,35	469.892,17	483.620,52
	U.M.	**TRASPORTO**	**FINE VITA**	**TOTALE**
GWP Effetto serra	kgCO2eq	1.006,75	32.344,85	33.351,60
	U.M.	**TRASPORTO**	**FINE VITA**	**TOTALE**
AP Acidificazione	KgSO2eq	9,0607	105,0901	114,1508
	U.M.	**TRASPORTO**	**FINE VITA**	**TOTALE**
EP Eutrofizzazione	KgPO4eq	1,4644	8,8837	10,3481
	U.M.	**TRASPORTO**	**FINE VITA**	**TOTALE**
POCP Smog estivo	kgC2H4eq	1,7389	22,3509	24,0898
	U.M.	**TRASPORTO**	**FINE VITA**	**TOTALE**
Potere calorifico	MJ	-	109.169,34	109.169,34

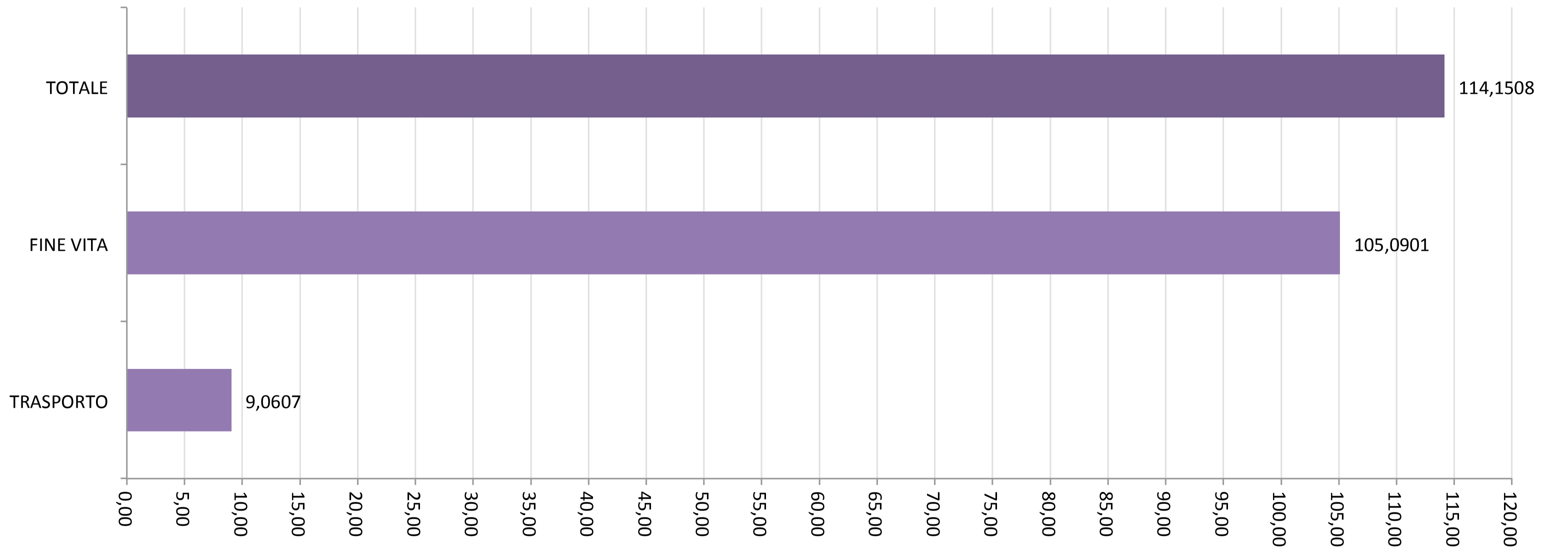
PEI non rinnovabile



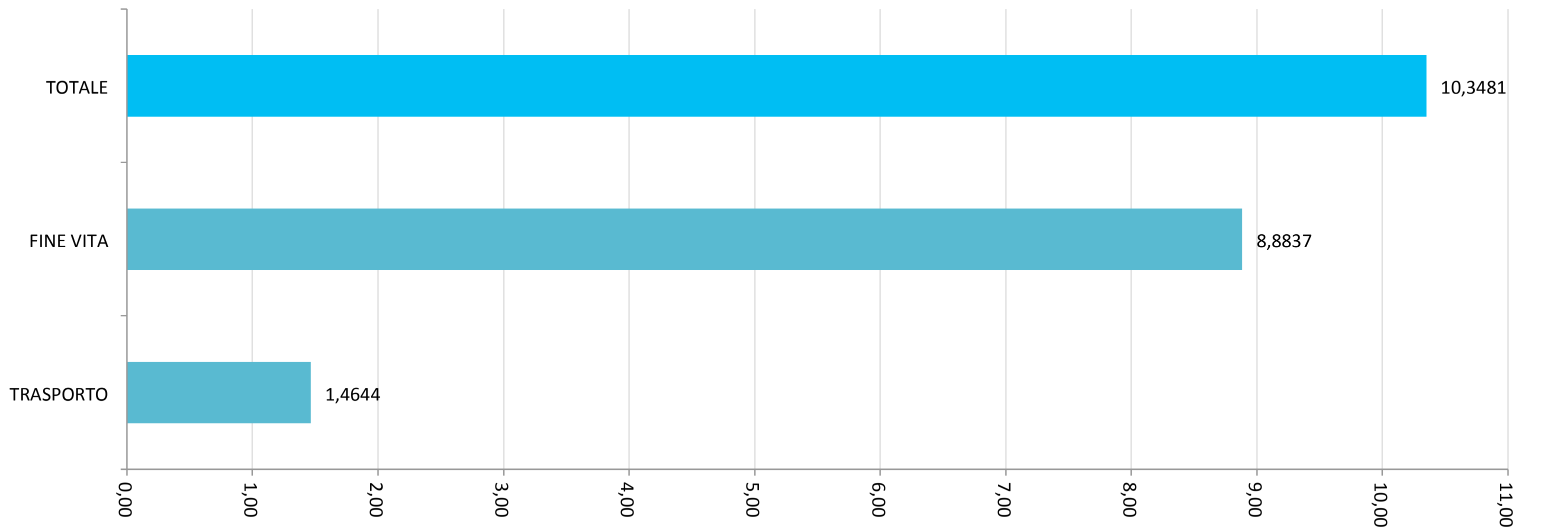
GWP Effetto serra



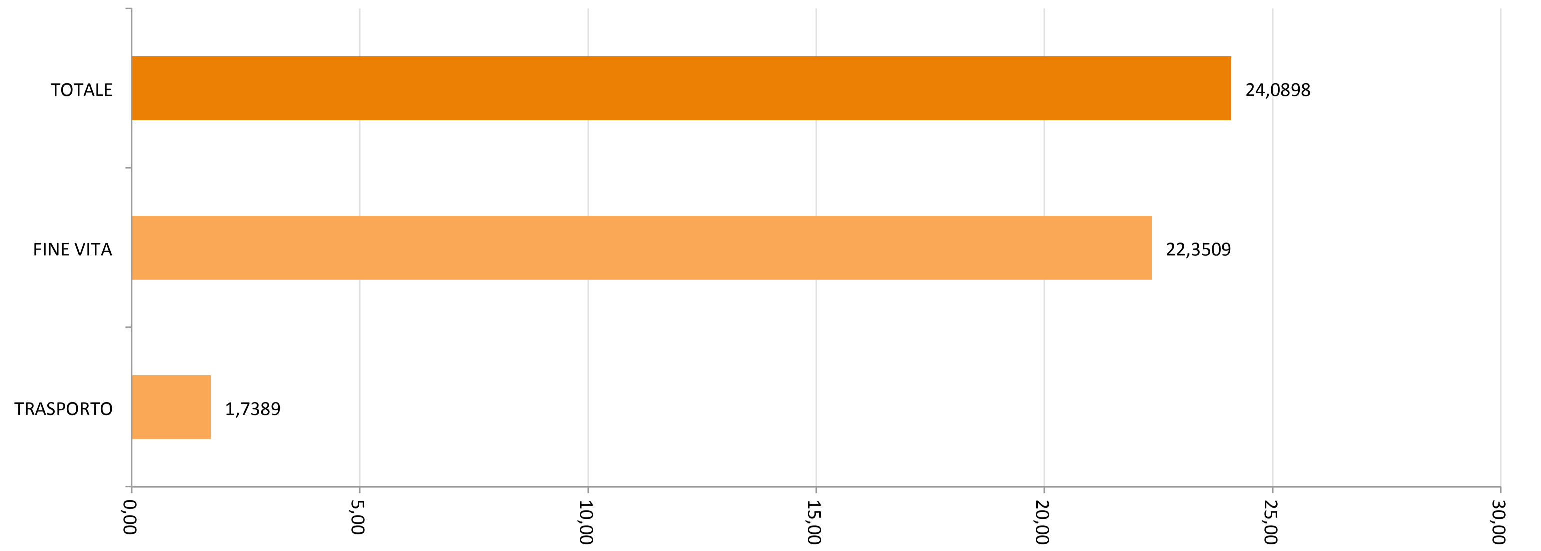
AP Acidificazione



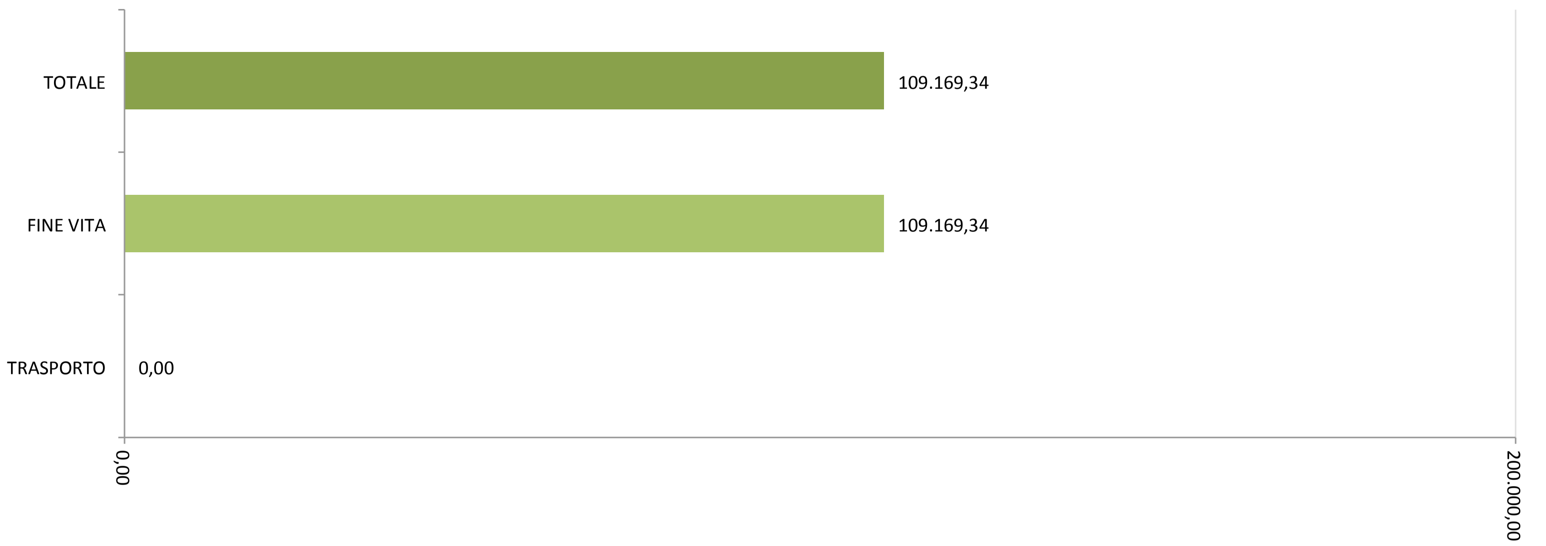
EP Eutrofizzazione



POCP Smog estivo

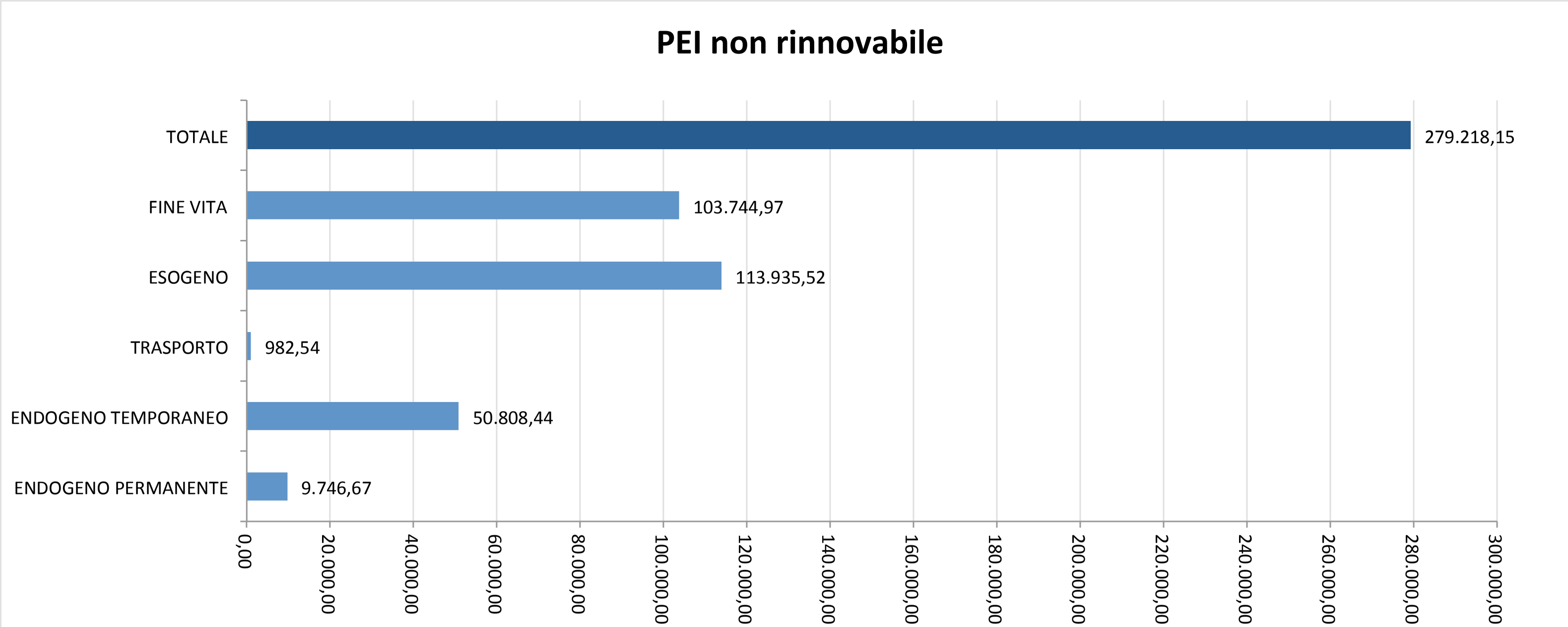


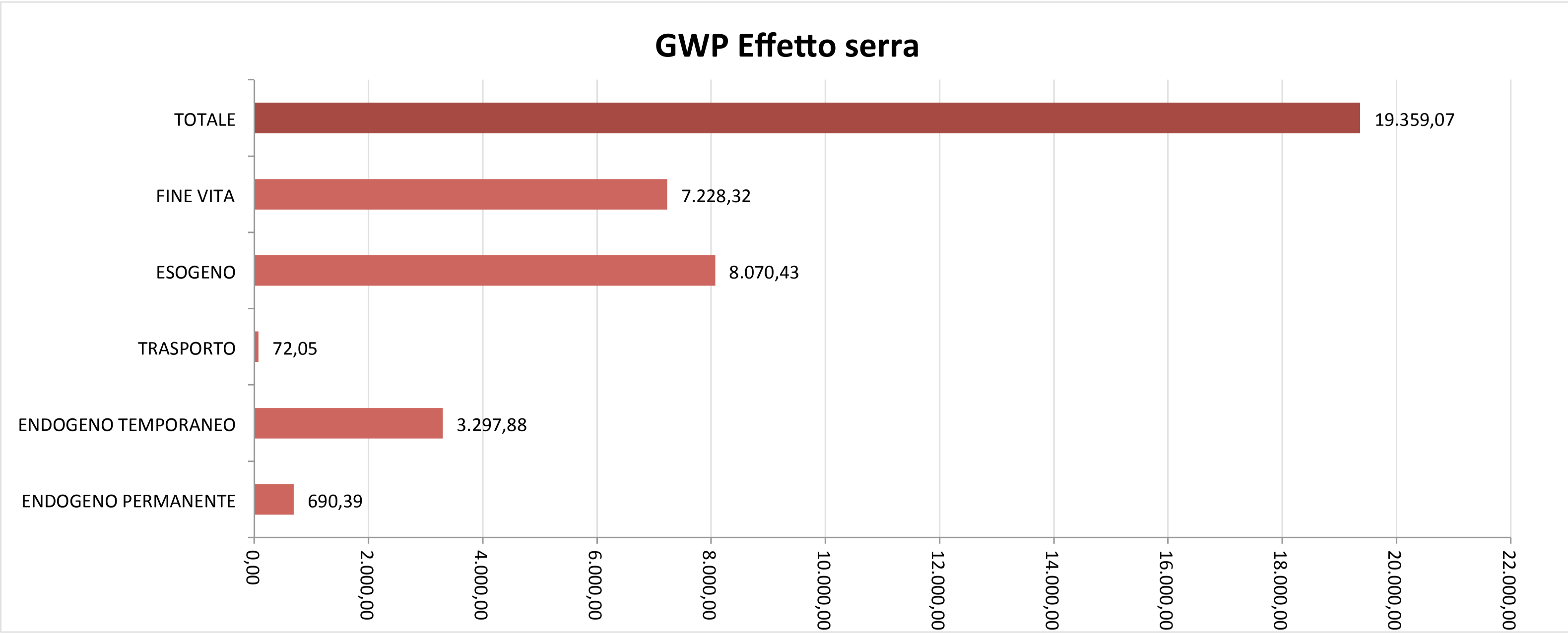
Potere calorifico

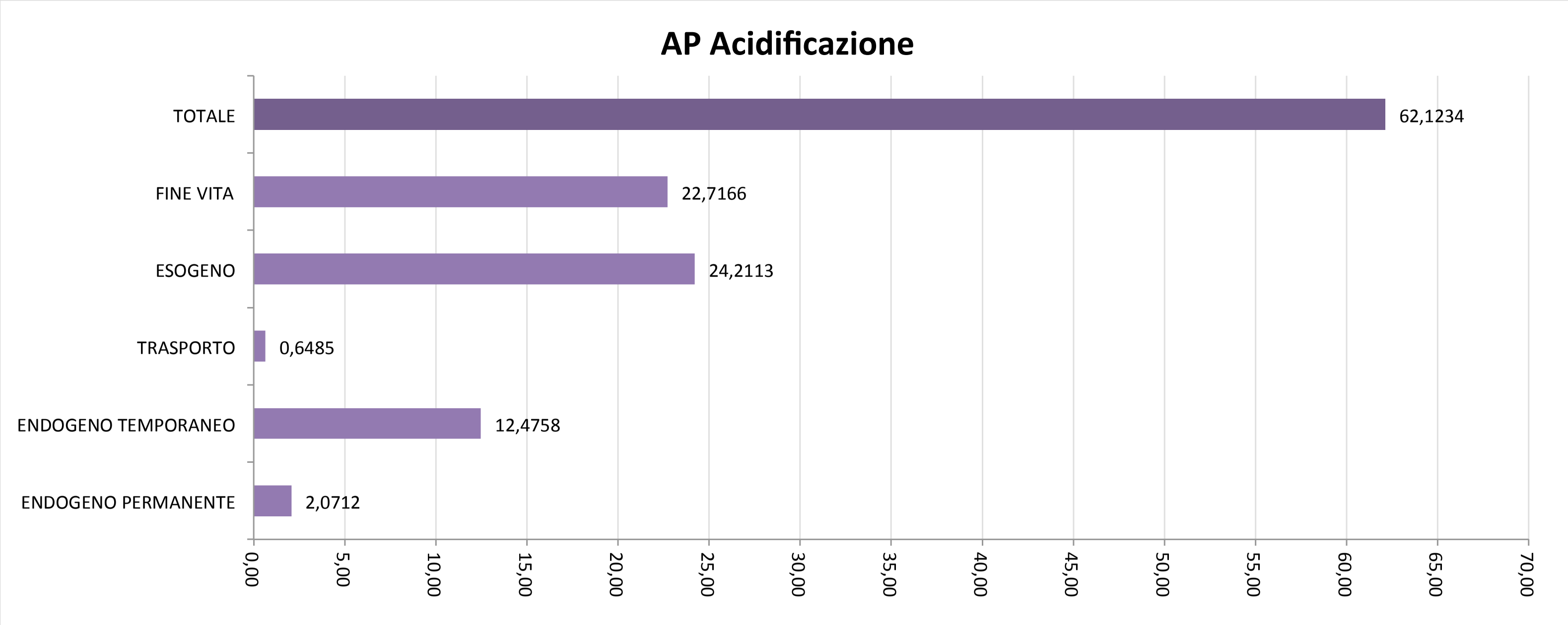


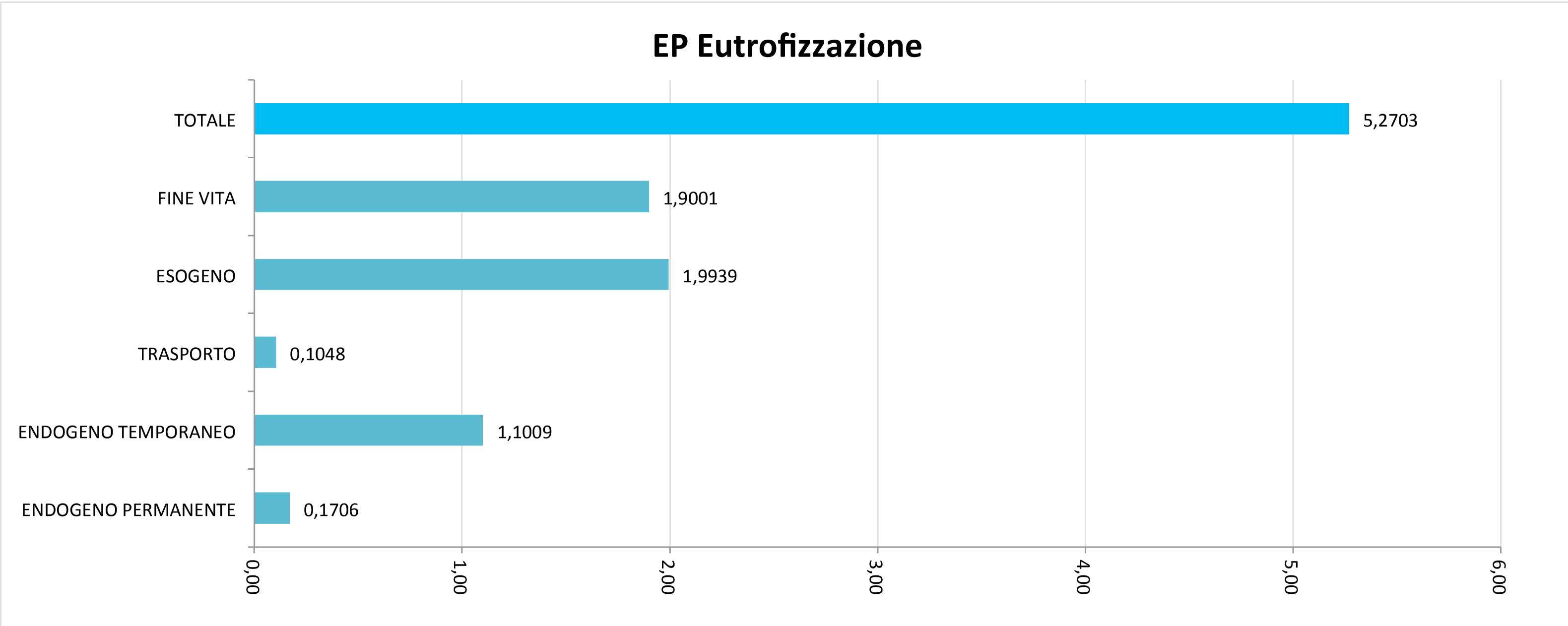
L'IMPRESA ACQUISISCE LA PROPRIETA' DEI SISTEMI DI MESSA IN SICUREZZA

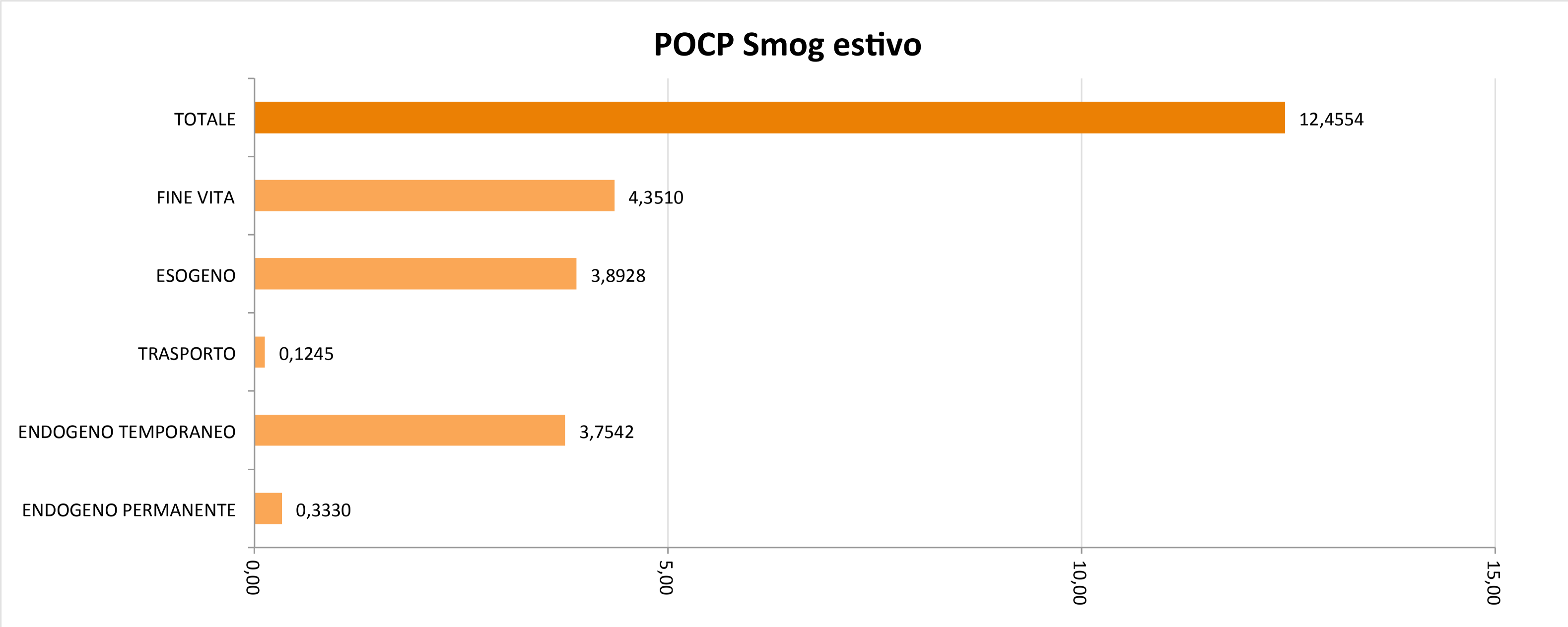
	U.M.	ENDOGENO PERMANENTE	ENDOGENO TEMPORANEO	TRASPORTO	ESOGENO	FINE VITA	TOTALE
PEI non rinnovabile	MJ	9.746,67	50.808,44	982,54	113.935,52	103.744,97	279.218,15
	U.M.	ENDOGENO PERMANENTE	ENDOGENO TEMPORANEO	TRASPORTO	ESOGENO	FINE VITA	TOTALE
GWP Effetto serra	kgCO2eq	690,39	3.297,88	72,05	8.070,43	7.228,32	19.359,07
	U.M.	ENDOGENO PERMANENTE	ENDOGENO TEMPORANEO	TRASPORTO	ESOGENO	FINE VITA	TOTALE
AP Acidificazione	KgSO2eq	2,0712	12,4758	0,6485	24,2113	22,7166	62,1234
	U.M.	ENDOGENO PERMANENTE	ENDOGENO TEMPORANEO	TRASPORTO	ESOGENO	FINE VITA	TOTALE
EP Eutrofizzazione	KgPO4eq	0,1706	1,1009	0,1048	1,9939	1,9001	5,2703
	U.M.	ENDOGENO PERMANENTE	ENDOGENO TEMPORANEO	TRASPORTO	ESOGENO	FINE VITA	TOTALE
POCP Smog estivo	kgC2H4eq	0,3330	3,7542	0,1245	3,8928	4,3510	12,4554
	U.M.	ENDOGENO PERMANENTE	ENDOGENO TEMPORANEO	TRASPORTO	ESOGENO	FINE VITA	TOTALE
Potere calorifico	MJ	-	-	-	-	55.925,27	55.925,27

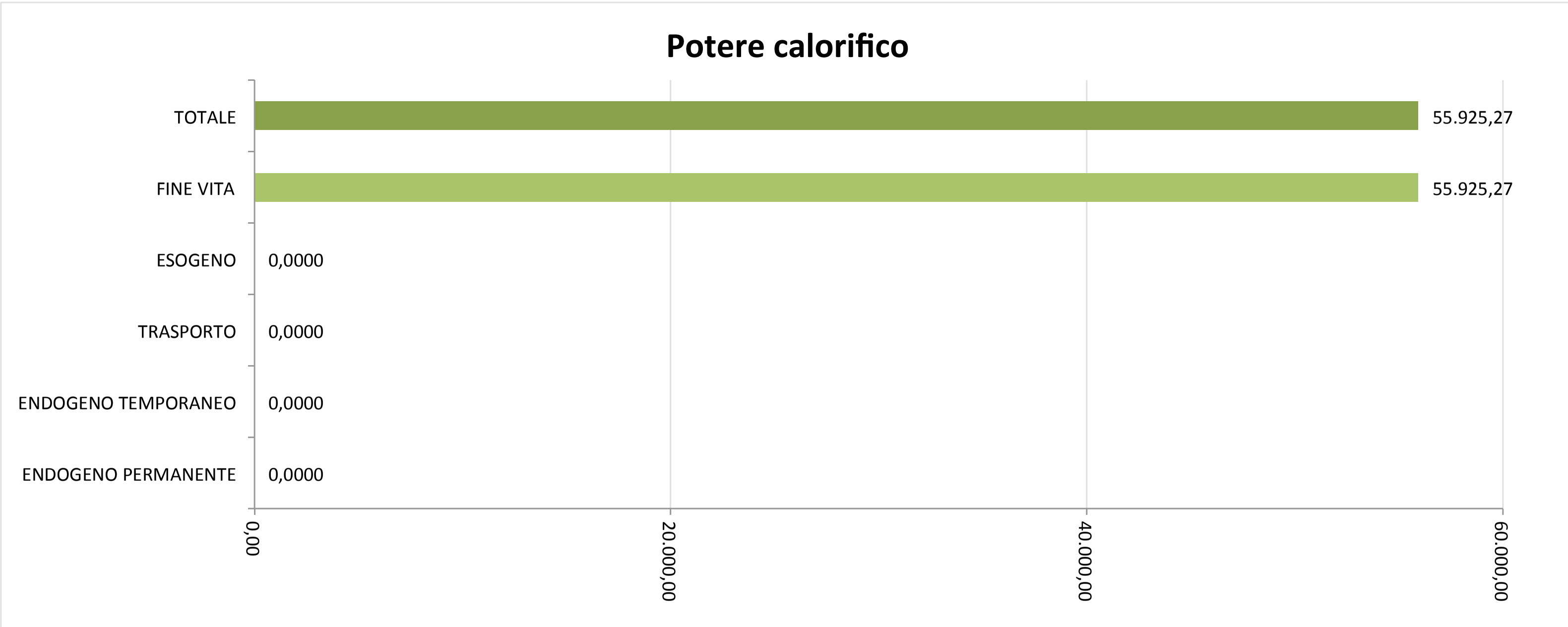

PEI non rinnovabile
TOTALE
FINE VITA
ESOGENO
TRASPORTO
ENDOGENO TEMPORANEO
ENDOGENO PERMANENTE
279.218,15
103.744,97
113.935,52
982,54
50.808,44
9.746,67
0,00
20.000,00
40.000,00
60.000,00
80.000,00
100.000,00
120.000,00
140.000,00
160.000,00
180.000,00
200.000,00
220.000,00
240.000,00
260.000,00
280.000,00
300.000,00


GWP Effetto serra
TOTALE
FINE VITA
ESOGENO
TRASPORTO
ENDOGENO TEMPORANEO
ENDOGENO PERMANENTE
19.359,07
7.228,32
8.070,43
72,05
3.297,88
690,39
0,00
2.000,00
4.000,00
6.000,00
8.000,00
10.000,00
12.000,00
14.000,00
16.000,00
18.000,00
20.000,00
22.000,00


AP Acidificazione
TOTALE
FINE VITA
ESOGENO
TRASPORTO
ENDOGENO TEMPORANEO
ENDOGENO PERMANENTE
62,1234
22,7166
24,2113
0,6485
12,4758
2,0712
0,00
5,00
10,00
15,00
20,00
25,00
30,00
35,00
40,00
45,00
50,00
55,00
60,00
65,00
70,00


EP Eutrofizzazione
TOTALE
FINE VITA
ESOGENO
TRASPORTO
ENDOGENO TEMPORANEO
ENDOGENO PERMANENTE
5,2703
1,9001
1,9939
0,1048
1,1009
0,1706
0,00
1,00
2,00
3,00
4,00
5,00
6,00


POCP Smog estivo
TOTALE
FINE VITA
ESOGENO
TRASPORTO
ENDOGENO TEMPORANEO
ENDOGENO PERMANENTE
12,4554
4,3510
3,8928
0,1245
3,7542
0,3330
0,00
5,00
10,00
15,00


Potere calorifico
TOTALE
FINE VITA
ESOGENO
TRASPORTO
ENDOGENO TEMPORANEO
ENDOGENO PERMANENTE
55.925,27
55.925,27
0,0000
0,0000
0,0000
0,0000
0,00
20.000,00
40.000,00
60.000,00