UNIVERSITAT POLITÈCNICA DE VALÈNCIA

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School of Architecture

Timber Joints
Development of a Support and Beam Joint Catalogue

End of Degree Project

Bachelor's Degree in the Fundamentals of Architecture

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Abstract:

The purpose of this catalogue is to collect recent publications regarding the topic of timber joints and present the information obtained in a clear, intuitive manner. This was carried out with an initial digestion of the appropriate publications, followed by several classifications, that are reflected in an interactive table formatted catalogue, along with specific information sheets for each joint.

Among the presented information, we find compatibility of timber types, fastening mechanisms and element dispositions. The correlations and admissible conditions between these factors can be easily examined, allowing for informed choices of joint solutions.

This paper additionally proves how it is in the interest of the professional, to determine the type of timber being employed, the fastening elements´ impact on the members, and therefore, the correct type of joint in each situation.

Key words:

Timber, Structure, Joints, Catalogue, Semirigid Joint, Glued Laminated Timber, Sawn Timber.

Resumen:

El propósito de este catálogo es reunir publicaciones recientes sobre el tema de las uniones de madera y presentar la información obtenida de manera clara e intuitiva. Esto se ha llevado a cabo con una digestión inicial de las publicaciones adecuadas, seguida de varias clasificaciones, que se reflejan en un catálogo en forma de tabla interactiva, junto con fichas informativas específicas para cada unión.

Entre la información presentada, encontramos compatibilidades de tipos de madera, mecanismos de fijación y disposiciones de los elementos. Las correlaciones y condiciones admisibles entre estos factores pueden ser examinadas fácilmente, lo que permite elegir soluciones de uniones de manera informada.

Este documento demuestra, además, cómo es de interés para el profesional determinar el tipo de madera que se está utilizando, el impacto de los elementos de fijación sobre los miembros y, por lo tanto, el tipo correcto de unión para cada situación.

Palabras clave:

Madera, Estructura, Uniones, Catálogo, Unión Semirrígida, Madera Encolada Laminada, Madera Aserrada.

Resum:

El propòsit d'aquest catàleg és reunir publicacions recents sobre el tema de les unions de fusta i presentar la informació obtinguda de manera clara i intuitiva. Això s'ha dut a terme amb una digestió inicial de les publicacions adequades, seguida de diverses classificacions, que es reflecteixen en un catàleg en forma de taula interactiva, juntament amb fitxes informatives específiques per a cada union.

Entre la informació presentada, trobem compatibilitats de tipus de fusta, mecanismes de fixació i disposicions dels elements. Les correlacions i condicions admisibles entre aquests factors poden ser examinades fàcilment, cosa que permet escollir solucions d'unions de manera informada.

Aquest document demostra a més, com és d'interès per al professional determinar el tipus de fusta que s'està utilitzant, l'impacte dels elements de fixació sobre els objectes i, per tant, el tipus correcte d'unió per a cada situació.

Paraules clau:

Fusta, Estructura, Unions, Catàleg, Unió Semirrigida, Fusta Engreixada Laminada, Fusta Serrellada.

Index

1. Introduction

1.1 Motivation and Objectives

The following research work collects and organizes types of joints between timber beams and supports in the form of an interactive table formatted catalogue, considering the arrangement of the elements to be joined, the load-bearing mechanism that counters the applied forces, and whether the solution applies to sawn, laminated timber, or both.

It aims to collect recent publications regarding the topic of timber joints and express the information in a pleasing format, through unified graphism and specific joint page design.

It is expected that this structured information on the design of timber joints, along with their limitations and opportunities, will promote their use in construction projects.

"The success of timber structures depends to a significant degree on the joint details employed. ... They can dictate the final member size, consume up to 70% of the design effort, and if not carefully detailed be visually unattractive"

[Batchelar McIntosh, 1998]

1.2 Alignment with the SDG´

Informing students and professionals about existing techniques and recent innovations can, in turn, spark interest in research and further development of structural joints, be it timber or other materials, aligning with SDG 9 – Industry, Innovation, and Infrastructure.

.

To analyze this catalogue's relevance to SDG 11 - Sustainable Cities, SDG 12 - Responsible Consumption and Production, SDG 13 - Climate Action and SDG 15 - Life on Land Communities, we must first evaluate the conditions under which timber structures can be a more sustainable alternative than steel or concrete ones.

Production Phase

"In the interest of evaluating structural materials´ CO2 emissions during production phase [A1-A3], I will remit to "*Comparative LCA of a concrete and steel apartment building and a cross laminated timber apartment building*" [Eliassen et all, 2019]

During August 2018, and December 2018, two case buildings are completed, Maskinparken 2 and Maskinparken TRE, respectively.

Their key differences and features that serve the comparison are listed in the following table:

	Maskinparken 2	Maskinparken TRE
Gross internal area	2376,1 m^2	3784,8 m^2
Number of stories	5	8
Number of apartments	31	47
Construction system	Reinforced concrete and steel	CLT
Foundation	Concrete underground car park	Concrete underground car park
Façade	Aired plaster	Wood panelling
Balconies	Prefabricated concrete	CLT
Outer walls	Insulated stud work	Lined CLT walls

Fig.1 Differences between the two buildings [Eliassen et all, 2019]

A portion of the LCA is displayed in the following graphs:

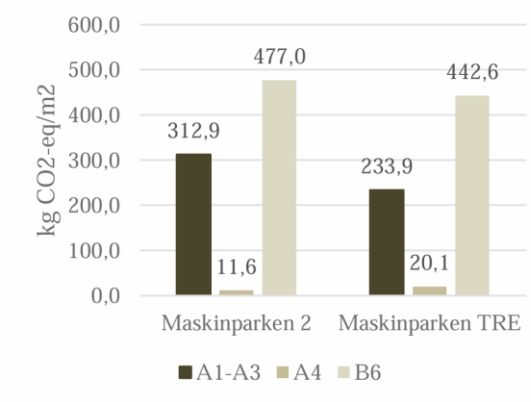

Fig.2.1 GHG emissions from Maskinparken 2 and TRE for the production stage (A1-A3), transport (A4) and operational energy use (B6). [Eliassen et all, 2019]

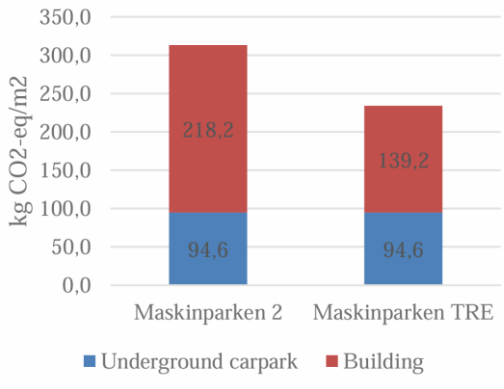

Fig.2.2 GHG emissions from the underground car park and the building (A1-A3). [Eliassen et all, 2019]

"*When looking at the production stage alone, Maskinparken 2 has a greenhouse gas emission of 312,9 kg CO2-eq/m2, while Maskinparken TRE has an emission of 233,9 kg CO2-eq/m2.*" [Eliassen et all, 2019]

Transport

This is a key phase in timber structures´ LCA. *"Life Cycle Assessment and Cost Analysis of Mid-Rise Mass Timber vs. Concrete Buildings in Australia"* [Rodwell et all, 2024], presents a theoretical case study of a mid-rise building, built either with concrete, local mass timber, or imported mass timber, and examines the worst- and best-case scenarios for each alternative.

"Transportation to the construction site was one area where the concrete building outperformed the MTC building. Concrete and steel required shorter transportation distances (about 30 km) … This reduced fuel consumption, emissions, and logistical complexities, …. In contrast, MTC, particularly imported mass timber, required longer transportation distances … imported timber from Austria traveling approximately 20,000 km." [Rodwell et all, 2024]

Reuse and Downcycling

Timber structure projects can often exhibit the reuse or downcycling of its elements, as a selling point.

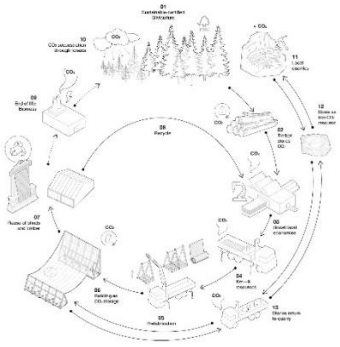

Fig.3 Circular Economy diagram. [Bouzas, 2022]

However, it can be argued that precast concrete and steel structures can lend themselves to reuse as well, which leaves the downcycling of timber into wood pellets for energy production as its distinctive end-of-life use.

This use is controlled and limited. The ENplus Quality Certification for Wood Pellets disallows not only painted, treated or glued timber, but

demolition timber altogether. This is mainly due to concerns regarding emissions and equipment damage.

"*ENplus deviates from the standard ISO 17225-2; the use of demolition wood and of chemically treated wood is not allowed for any ENplus pellets.*" [ENplus Handbook, Part 3 - Pellet Quality Requirements]

For this action to be enforceable, the timber elements to be downcycled must fall into the following categories:

ENplus A1		ENplus A2		ENplus B	
1.1.3	Stem wood [a]	1.1.1	Whole trees without roots [a]	1.1	Forest, plantation and other virgin wood [a]
1.2.1	Chemically untreated by-products and residues from the wood processing industry [b]	1.1.3	Stem wood [a]	1.2.1	Chemically untreated by-products and residues from the wood processing industry [b]
		1.1.4	Logging residues [a]		
		1.2.1	Chemically untreated by-products and residues from the wood processing industry [b]	1.3.1	Chemically untreated used wood [c]

a) Wood which was externally treated with wood preservatives against insect attack (e.g. lineatus), is not considered as chemically treated wood. If all chemical parameters of the pellets comply with the limits and/or concentrations are too small to be concerned with.
b) Negligible levels of glue, grease and other timber production additives used in sawmills during production of timber and timber product from virgin wood are acceptable, if all chemical parameters of the pellets are clearly within the limits and/or concentrations are too small to be concerned with.
c) Demolition wood is excluded. Demolition wood is used wood coming from the demolition of buildings or civil engineering installations.

Fig. 4 Wood types that are permitted to be used for wood pellet production [ENplus, 2015]

Raw Material Harvesting

Responsible management of resources is not an intrinsic advantage of the employment of timber; it is dependent on the manufacturer.

"...extreme caution is warranted when stocks of renewable resources are allowed to diminish. To avoid losses being overlooked, clarity is needed about exactly what is being sustained"

[Putz, Romero, Sist, Schwartz, Thompson, Roopsind, Ruslandi, Medjibe, Ellis. 2022]

For this catalogue to align with the aforementioned Sustainable Development Goals, it must be stated that sustainable management of forest resources and reforestation practices, can be positive outcomes of timber production, provided the manufacturers abide by the law, and possess the required certifications.

"Sustainable Timber Yield is possible but often requires cutting cycles that are longer and logging intensities that are lower than prescribed by law, as well as effective use of low-impact logging practices and application of silvicultural treatments to promote timber stock recovery. These departures from business-as-usual practices will lower profit margins but generally benefit biodiversity and ecosystem services"

[Putz, Romero, Sist, Schwartz, Thompson, Roopsind, Ruslandi, Medjibe, Ellis. 2022]

Finance:

Comparing the costs of glulam, and steel structures using the IVE construction costs databases, we find the following:

Fig. 5.1 Screenshot from IVE website, 2025

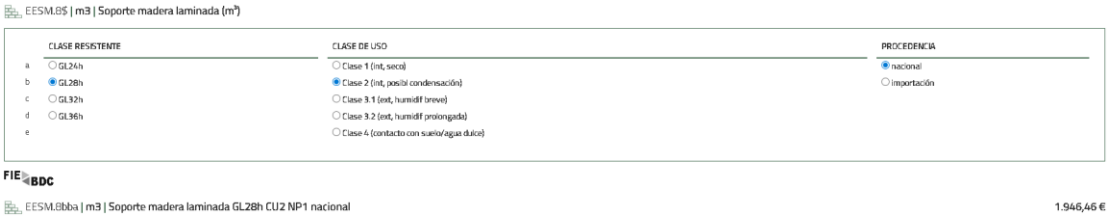

Fig. 5.2 Screenshot from IVE website, 2025

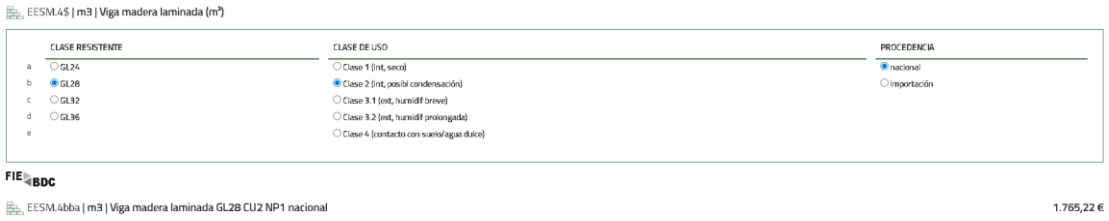

Fig. 5.3 Screenshot from IVE website, 2025

With these unitary values, and assuming the density of GL24c-32c timber to be 365-400 kg/m3 [ISO/TR 19623:2019] (assumed value: 382,5 kg/m3), we can compare the value of both structures per kg:

Timber beam prize per kg: 4,64 €
Timber beam prize per kg: 5.09 €

- Average timber structure prize per kg: 4,87 €
- Steel structure prize per kg: 2,49 €

Another indicator can be "*Comparison of Building Construction and Life-Cycle Cost for a High-Rise Mass Timber Building with its Concrete Alternative*" [Gu et all, 2020], which analyzed a 12-story mixed use office and apartment complex, in Portland, Oregon.

The costs presented in the following table were quoted from the RS Means 2018 database:

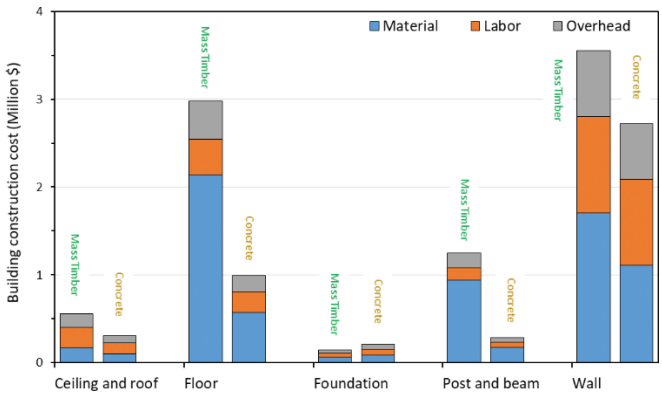

Fig. 6 Front-end construction costs by assembly type for high-rise mass timber and concrete buildings [Gu et all, 2020]

From this evaluation we can reasonably formulate potentials and limitations regarding ODS´ 11, 12, 13 and 15 of the timber structures this catalogue builds on.

Timber structures pose significant cuts in greenhouse gas emissions during their production phase, that can be rendered insignificant if transport logistics prove excessive.

Downcycling can be practiced only in a reduced spectrum of timber elements, and reuse of the structural elements can be practiced in precast concrete, steel and timber structures.

The cost of timber structures is generally in the range of 2 times the cost of steel structures.

A careful dimensioning and mindful choice of timber elements and supplier is therefore key in assessing whether the timber structures encouraged by this catalogue align with the aforementioned SDG´s.

1.3 Methodology and Depth of Analysis

The solutions described in this catalogue have been compiled from physical and digital publications, digital repositories, Industry catalogues, and research documents.

After a selection process regarding the joints´ relevance in a construction setting, and suitability for classification and comparison, they are narrowed down into a general collection,

Once the general collection is generated, the joints are classified according to parameters that help the navigation process across the catalogue.

To present the solutions graphically, a uniform axonometric representation style has been adopted, in this way, previously developed external documentation will be redrawn to present a cohesive and coherent catalogue.

The catalogue will be presented as a hyperlinked “Quick Search” table, classification within this table will be described in further sections.

When a cell in the table containing a joint is clicked, the user is rerouted to the joints` specific page, where they can find:

- Existing examples of the joint in a construction setting.
- A brief contextualization of its fields of application.
- A deeper graphical analysis of the execution and its load bearing mechanism, as well as the elements needed.
- An orientation on what documents and aid to consult when calculating and designing the joint.

In regard to the last point, the basic documents to be consulted when designing the joints will be listed, as well as calculation aids, that include a spreadsheet developed by Bárbara Galvez Gabarda in 2011, and manufacturers´ catalogues.

2. Joint Catalogue

2.1 Classification

All joints in this catalogue are assumed to be semirigid, following the conclusions of Leichti et all, 1999.

"It seems unlikely that a fully rigid joint can be designed for use in timber portal frames because of stiffness orthotropy. However, moment-resisting joints that are less than 50% rigid can be used in timber frames to develop frame- like behavior." [Leichti et all, 1999]

A conclusion later supported by Liu, in 2018.

2.1.1 Element Disposition

Across the columns of the Quick Search Table, the joint collection is classified under three element dispositions.

This form of classification is drawn from the "Timber Frame Headquarters" joint library, 2015, where the joint solutions offered appear organized according to the disposition of the elements, with respect to one another.

In favor of a more compact catalogue, joints that offer little alternative solutions to be executed have been overlooked, focusing on dispositions, more prone to extrapolation.

The first two, address joints between a single support and a single beam. The first disposition places the beams` cross section against the support, resulting in a vertical contact plane. (fig.7.1.).

The second, places the beam over the supports` cross section, resulting in a horizontal contact plane. (fig.7.2.).

The last, addresses joints between a single support, and two sets of beams, perpendicular to one another. (fig.7.3.).

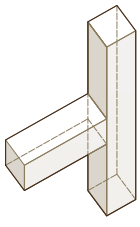

Fig.7.1 Own elaboration

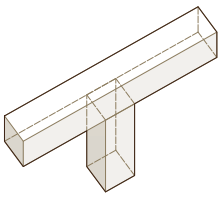

Fig.7.2 Own elaboration

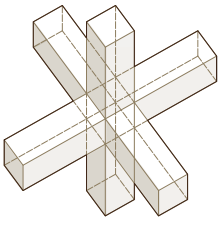

Fig.7.3 Own elaboration

The dispositions adopted are general cases, simplified with their directrix concurring in the joints at a 90-degree angle with respect to one another.

However, as we will see in the joints´ specific pages` photographic documentation, the solutions analyzed can often be particularized for joints with elements of differing angles of concurrence.

2.1.2 Load Bearing Mechanism

Along the rows of the Quick Search Table, the joint collection is classified under 3 main categories, color-coded and subdivided into specific fastening elements, with their corresponding load bearing mechanism.

This form of classification is drawn from "Eurocode 5: Design of timber structures" and "DCA-6 2015". Both documents tackle the analysis of joints, their calculation and geometric limitations, depending on the fastening pieces´ type and material.

- Timber Elements and Adhesives.
    - Wooden Dowels. ("Pegs") — Traction and Shear
    - Mortise and Tenon, wedged. — Traction and Shear

- Steel Elements
    - Rod, nut and washer. (longitudinal) — Traction and Shear
    - Rod, nut and washer. (transversal) — Shear
    - Dented plate and nails — Shear
    - T-Joint Piece — Traction and Shear
    - Hook Piece — Traction and Shear
    - Dovetail Piece — Traction and Shear
    - Hanger Piece — Shear

- Case Study Joints
    - Steel Slings. — Friction Grip
    - Rod, nut, washer and plate. — Shear

2.1.3 Suitable Timber

To provide a more complete set of information at first glance, the joints are marked as valid for application on sawn, laminated timber, or both. Said markers are shown below.

Laminated

Fig.8. Own elaboration

Sawn

Fig.8.2 Own elaboration

For the assessment of their scope of application, the manufacturer catalogues for the fastening elements have been consulted, and for the case study joints, their publications, and physical prototypes

2.1.4 Specific Joint sheet design.

The specific pages of this catalogue, dedicated to each joint, are structured in the following manner:

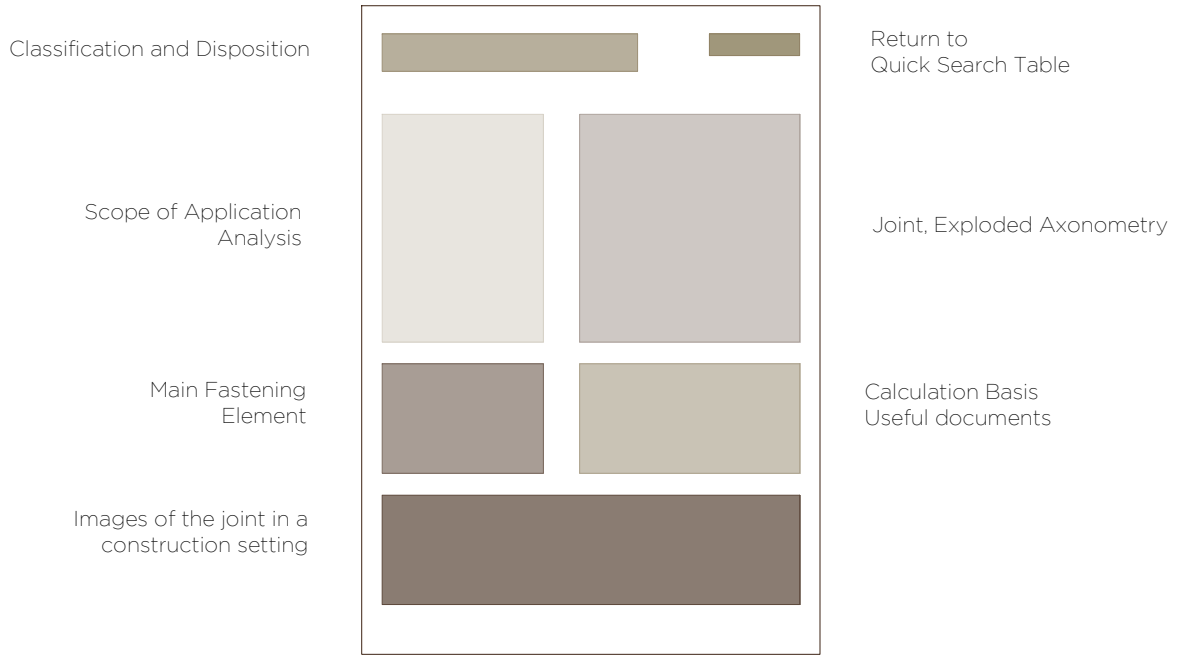

Fig.9 Own elaboration

2.2 Quick Search Table

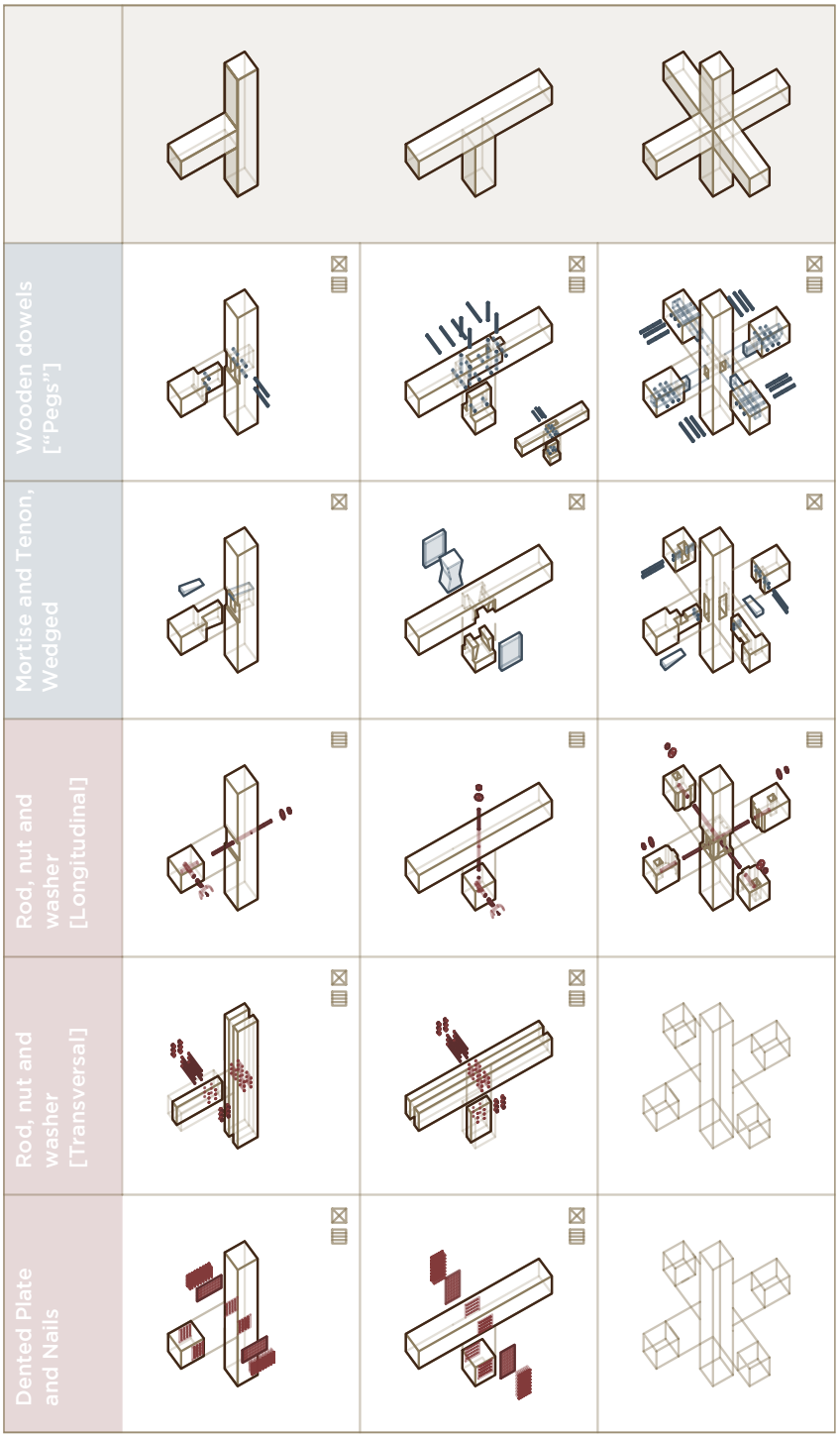

Fig.10.1 Quick Search table 1/2 [Own elaboration]

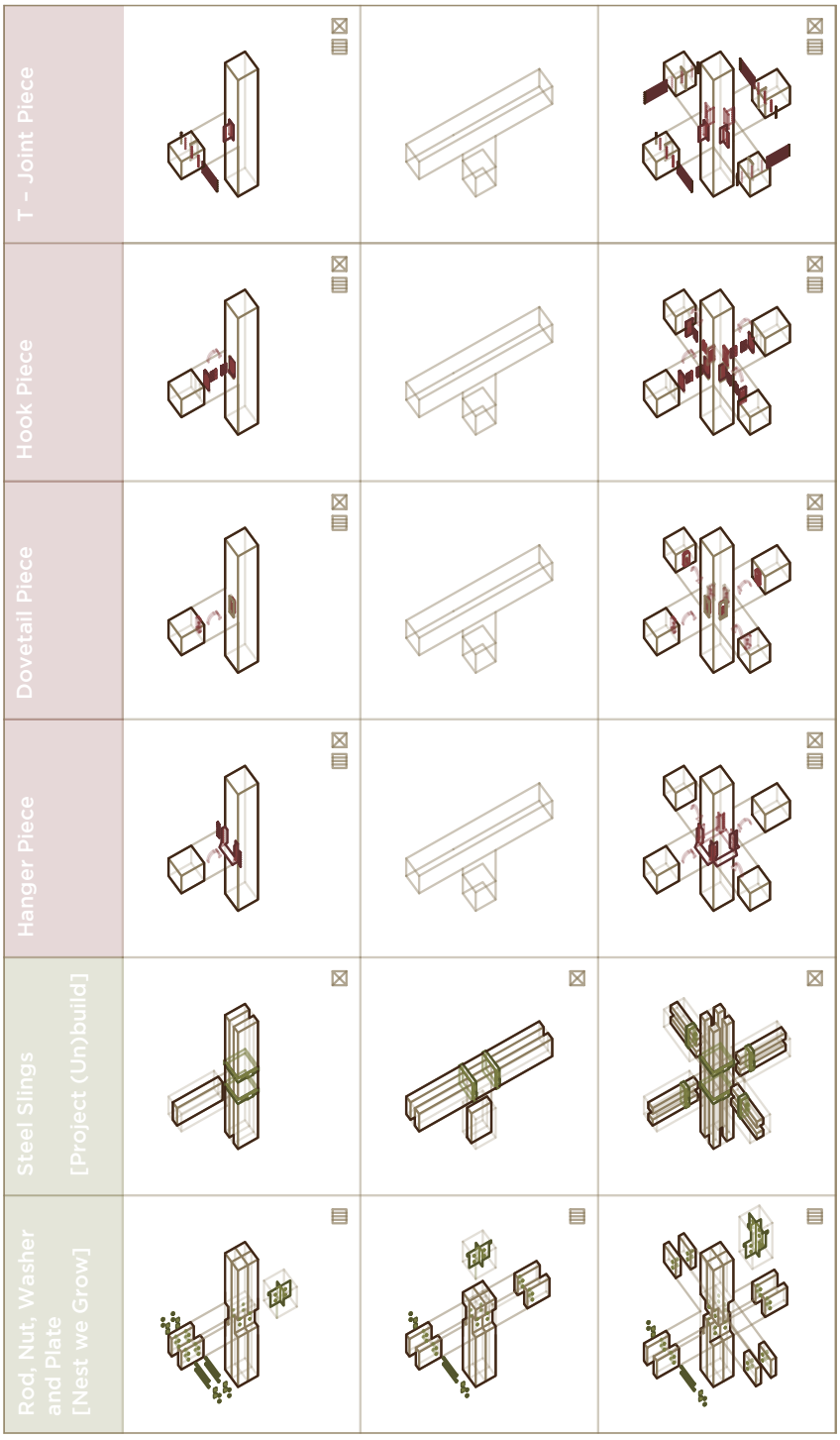

Fig.10.2 Quick Search table 2/2 [Own elaboration]

2.3 Wooden Dowels (“Pegs”).
2.3.1 Disposition 1

Scope of Application:

“Wooden dowels (treenails) have long been used to fasten joints in timber construction, particularly mortise and tenon joints. Their applications span from furniture making to timber framing in buildings, where they are commonly used to secure beams to posts in small to medium timber structures”

[USDA, 2010]

Supported by Chappell, 2011.

Supported by USDA, 2021:

“Some examples of strong connections are dowels, mortise and tenons, and rabbets.... Because wood swells so much more across the grain than along the grain, moisture changes in these joints produce large internal stresses.”

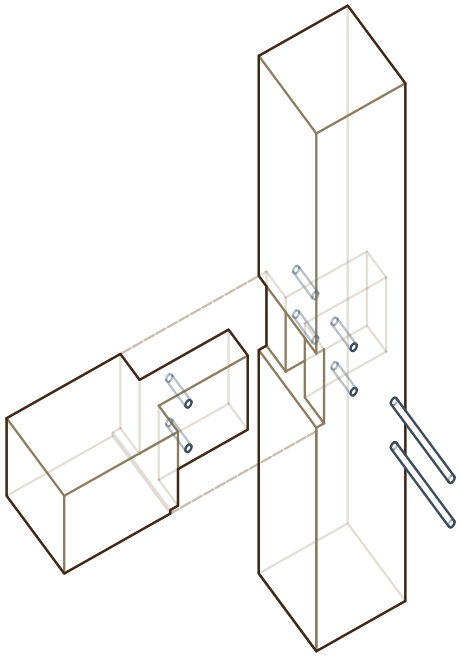

Fig.11 Own elaboration

Fastening Elements:

Fig.12 Rounded Oak Dowels
[UK OAK, 2025]

Calculation basis:

CTE DB SE-M:

Microsoft Word - CTE DB SE-M-diciembre2019-limpio.doc

Calculation Spreadsheet with disposition limitations:

https://riunet.upv.es/handle/10251/12473
[Gálvez Gabarda, B., 2011]

UNE EN-338 and UNE EN-1194

Fig.13 Joint photograph
[Aires, 2025]

Fig.14 Construction photograph
[Worzalla Brothers, 2024]

Fig.15 Joint photograph
[Appalachian+woods, 2025]

2.3.2 Disposition 2

Scope of Application:

"Wooden dowels (treenails) have long been used to fasten joints in timber construction, particularly mortise and tenon joints. Their applications span from furniture making to timber framing in buildings, where they are commonly used to secure beams to posts in small to medium timber structures"

[USDA, 2010]

Supported by Chappell, 2011.

Supported by USDA, 2021:

"Some examples of strong connections are dowels, mortise and tenons, and rabbets.... Because wood swells so much more across the grain than along the grain, moisture changes in these joints produce large internal stresses."

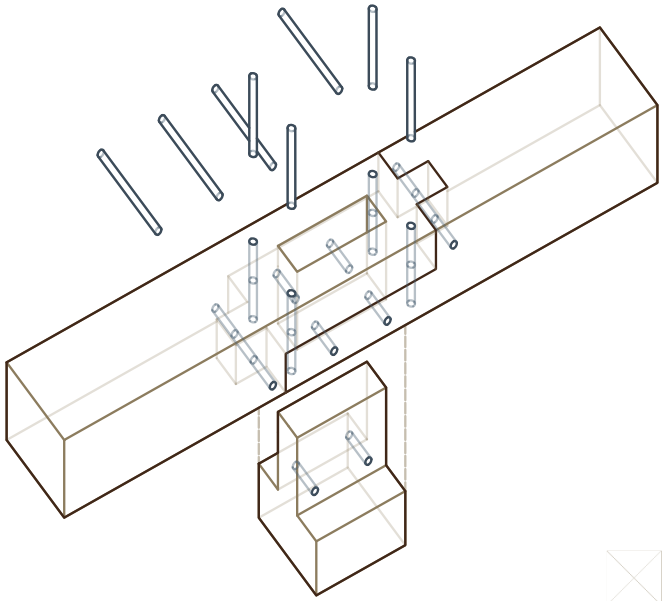

Fig.16 Own elaboration

:

Fastening Elements:

Fig.12 Rounded Oak Dowels
[UK OAK, 2025]

Calculation basis:

CTE DB SE-M:

Microsoft Word - CTE DB SE-M-diciembre2019-limpio.doc

Calculation Spreadsheet with disposition limitations:

https://riunet.upv.es/handle/10251/12473
[Gálvez Gabarda, B., 2011]

UNE EN-338 and UNE EN-1194

Fig.17 Construction photograph
[Forestry, 2025]

Fig.18 Joint photograph
[Forestry, 2025]

Fig.19 Joint photograph
[Forestry, 2025]

2.3.3 Disposition 3

Scope of Application:

"Wooden dowels (treenails) have long been used to fasten joints in timber construction, particularly mortise and tenon joints. Their applications span from furniture making to timber framing in buildings, where they are commonly used to secure beams to posts in small to medium timber structures"

[USDA, 2010]

Supported by Chappell, 2011.

Supported by USDA, 2021:

"Some examples of strong connections are dowels, mortise and tenons, and rabbets.... Because wood swells so much more across the grain than along the grain, moisture changes in these joints produce large internal stresses."

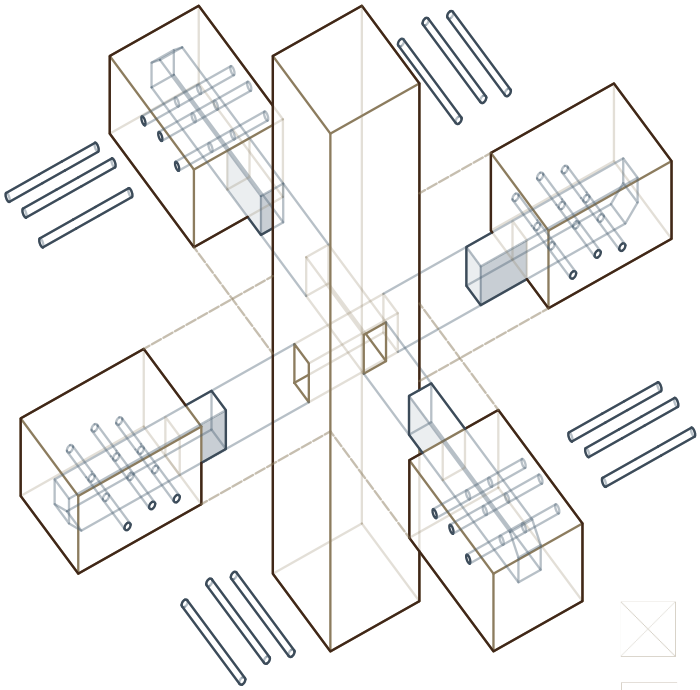

Fig.19 Own elaboration

Fastening Elements:

Fig.12 Rounded Oak Dowels
[UK OAK, 2025]

Calculation basis:

CTE DB SE-M:

Microsoft Word - CTE DB SE-M-diciembre2019-limpio.doc

Calculation Spreadsheet with disposition limitations:

https://riunet.upv.es/handle/10251/12473
[Gálvez Gabarda, B., 2011]

UNE EN-338 and UNE EN-1194

Fig.21 Joint photograph
[Friant, 2014]

Fig.18 Joint photograph
[Forestry, 2025]

Fig.19 Joint photograph
[Forestry, 2025]

2.4 Mortise and Tenon, Wedged

Quick-Search Table

2.4.1 Disposition 1

Scope of Application:

"Wedged mortise and tenon joints rely on the wedge to generate tension that locks the tenon in place, eliminating the need for nails or pegs. This type of joinery is frequently found in historic timber framing and is still used in traditional timber construction today."

[USDA, 2010]

"Wedged mortise and tenon joints are a hallmark of traditional timber framing. The tenon is driven into the mortise and then secured by driving a wooden wedge into a kerf at the end of the tenon. This creates a tight mechanical lock without the need for additional fasteners."

[Chappell, 2011]

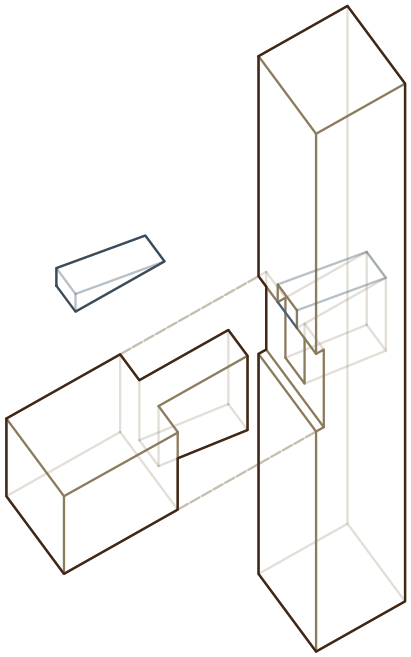

Fig.22 Own elaboration

Fastening Elements:

Fig.23 Timber Wedges
[MS Traders, 2025]

Calculation basis:

CTE DB SE-M:

https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:

https://riunet.upv.es/handle/10251/12473
[Gálvez Gabarda, B., 2011]

UNE EN-338 and UNE EN-1194

Fig.24 Construction photograph
[u/angry_timberframer, 2023]

Fig.25 Wedged mortise and tenon joint detail
[Timber Frame HQ, 2015]

Fig.26 Construction photograph
[TRC Timberworks, 2025]

2.4.2 Disposition 2

Scope of Application:

"Wedged mortise and tenon joints rely on the wedge to generate tension that locks the tenon in place, eliminating the need for nails or pegs. This type of joinery is frequently found in historic timber framing and is still used in traditional timber construction today."

[USDA, 2010]

"Wedged mortise and tenon joints are a hallmark of traditional timber framing. The tenon is driven into the mortise and then secured by driving a wooden wedge into a kerf at the end of the tenon. This creates a tight mechanical lock without the need for additional fasteners."

[Chappell, 2011]

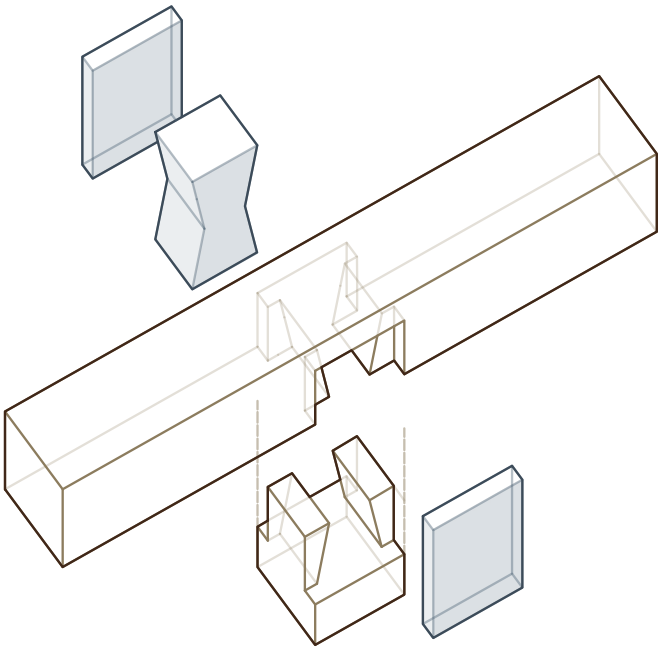

Fig.27 Own elaboration

Fastening Elements:

Fig.28 Bowtie Joint Piece
[BlackTail Studio, 2019]

Fig.29 Bowtie joint piece
[Donnie, 2025]

Calculation basis:

CTE DB SE-M:

https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:

https://riunet.upv.es/handle/10251/12473
[Gálvez Gabarda, B., 2011]

UNE EN-338 and UNE EN-1194

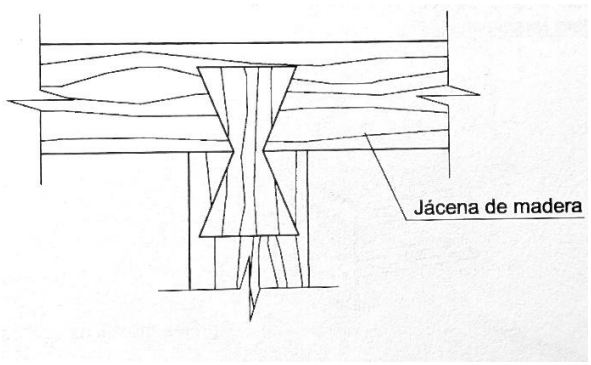

Fig.30 "Unión de pilar colgado de jácena"
[Urbán, 2014]

2.4.3 Disposition 3

Scope of Application:

"Wedged mortise and tenon joints rely on the wedge to generate tension that locks the tenon in place, eliminating the need for nails or pegs. This type of joinery is frequently found in historic timber framing and is still used in traditional timber construction today."

[USDA, 2010]

"Wedged mortise and tenon joints are a hallmark of traditional timber framing. The tenon is driven into the mortise and then secured by driving a wooden wedge into a kerf at the end of the tenon. This creates a tight mechanical lock without the need for additional fasteners."

[Chappell, 2011]

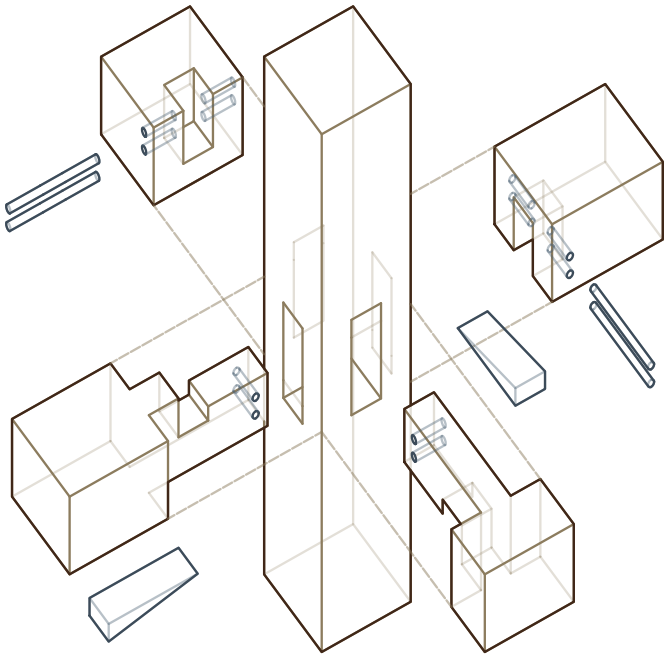

Fig.31 Own elaboration

Fastening Elements:

Fig.23 Timber Wedges
[MS Traders, 2025]

Fig.12 Rounded Oak Dowels
[UK OAK, 2025]

Calculation basis:

CTE DB SE-M:

https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:

https://riunet.upv.es/handle/10251/12473
[Gálvez Gabarda, B., 2011]

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Fig.24 Construction photograph
[u/angry_timberframer, 2023]

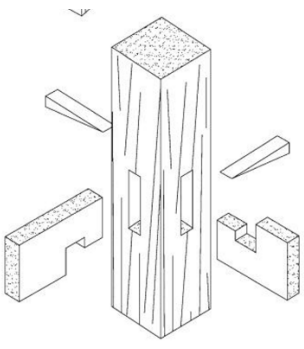

Fig.32 Joint detail: "Ensamble en diente y cuña"
[Urbán, 2014]

Fig.26 Construction photograph
[TRC Timberworks, 2025]

2.5 Rod, Nut and Washer. [Longitudinal]

2.5.1 Disposition 1

Scope of Application:

Ideal for longitudinal and transverse connections in timber subject to tension. Suitable for 12 or 16 mm diameter bolts or threaded rods

Disassembled by simply unscrewing the bolt Suitable for temporary structures or those that can be disassembled and reassembled

[Rothoblaas, 2024]

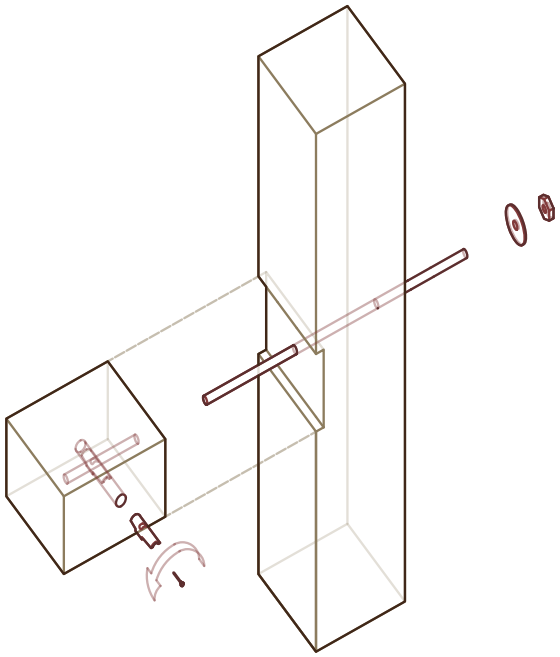

Fig.33 Own elaboration

Fastening Elements:

Fig.34 Simplex, removable concealed connector [Rothoblaas, 2024]

Calculation basis:

CTE DB SE-M:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:
https://riunet.upv.es/handle/10251/12473 [Gálvez Gabarda, B., 2011]

Rothoblaas Plates and Connectors for Timber 2024:
https://www.rothoblaas.com/catalogues-rothoblaas

UNE EN-338 and UNE EN-1194

CTE DB SE–A:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-A.pdf

Fig.35 Simplex, section illustration [Rothoblaas, 2024]

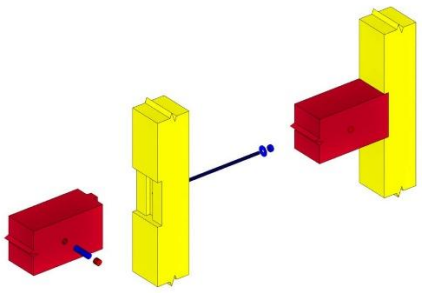

Fig.36 Exploded axonometry [Timber Frame HQ, 2015]

Fig.37 Construction photograph [Casalt, 2011]

2.5.2 Disposition 2

Scope of Application:

Ideal for longitudinal and transverse connections in timber subject to tension. Suitable for 12 or 16 mm diameter bolts or threaded rods

Disassembled by simply unscrewing the bolt Suitable for temporary structures or those that can be disassembled and reassembled

[Rothoblaas, 2024]

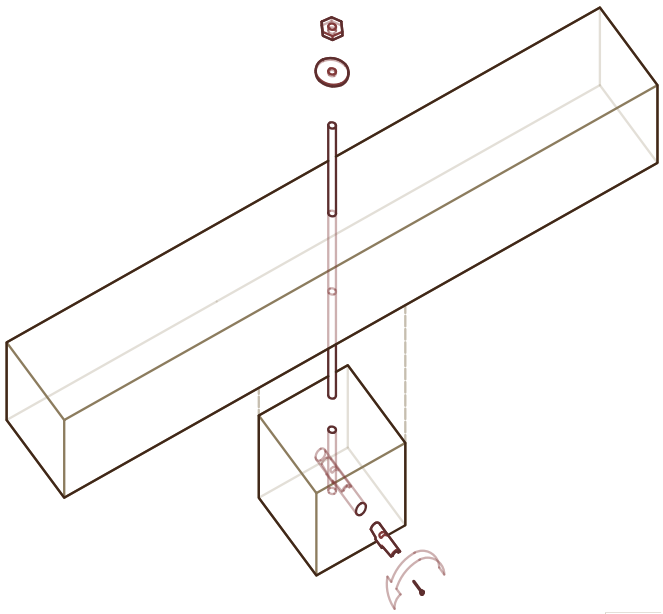

Fig.38 Own elaboration

Fastening Elements:

Fig.34 Simplex, removable concealed connector [Rothoblaas, 2024]

Calculation basis:

CTE DB SE-M:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:
https://riunet.upv.es/handle/10251/12473 [Gálvez Gabarda, B., 2011]

Rothoblaas Plates and Connectors for Timber 2024:
https://www.rothoblaas.com/catalogues-rothoblaas

UNE EN-338 and UNE EN-1194

CTE DB SE–A:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-A.pdf

Fig.35 Simplex, section illustration [Rothoblaas, 2024]

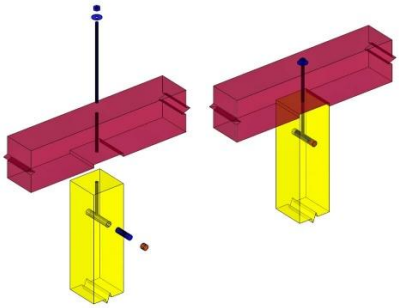

Fig.39 Exploded axonometry [Timber Frame HQ, 2015]

Fig.37 Construction photograph [Casalt, 2011]

2.5.3 Disposition 3

Scope of Application:

Ideal for longitudinal and transverse connections in timber subject to tension. Suitable for 12 or 16 mm diameter bolts or threaded rods

Disassembled by simply unscrewing the bolt Suitable for temporary structures or those that can be disassembled and reassembled

[Rothoblaas, 2024]

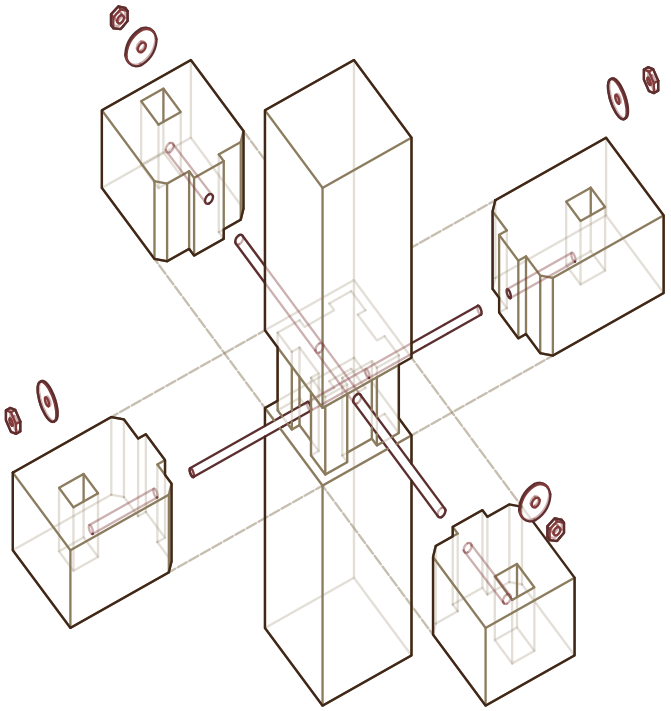

Fig.40 Own elaboration

Fastening Elements:

Fig.34 Simplex, removable concealed connector [Rothoblaas, 2024]

Calculation basis:

CTE DB SE-M:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:
https://riunet.upv.es/handle/10251/12473 [Gálvez Gabarda, B., 2011]

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UNE EN-338 and UNE EN-1194

CTE DB SE–A:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-A.pdf

Fig.35 Simplex, section illustration [Rothoblaas, 2024]

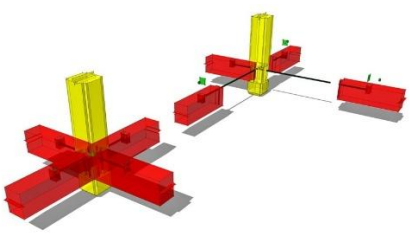

Fig.41 Exploded axonometry [Timber Frame HQ, 2015]

Fig.37 Construction photograph [Casalt, 2011]

2.6 Rod, Nut and Washer. [Transversal]
2.6.1 Disposition 1

Scope of Application:

Ideal for transverse connections in timber subject to tension. Suitable for 12 or 16 mm diameter bolts or threaded rods

Disassembled by simply unscrewing the bolt Suitable for temporary structures or those that can be disassembled and reassembled

[Rothoblaas, 2024]

Significant examples of the disassembly include Manuel Bouzas´ Mediterráneo Pavilion (Valencia) (fig 42, 43, 44) and Cabane 7L. (Rome). (fig 47, 48)

An example of assembly, disassembly, and reassembly in a different location, would be the winning proposal of AsIBs´ Ephemeral Bamboo Design competition 2025. (fig 46)

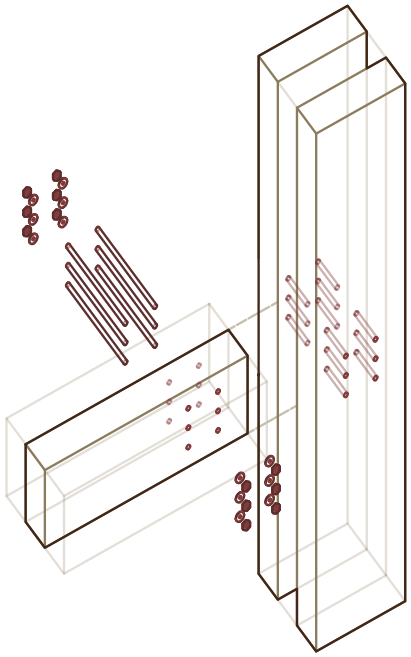

Fig.42 Own elaboration

Fastening Elements:

Fig.43 Rod, nuts and washers [Fixdex, 2025]

Calculation basis:

CTE DB SE-M:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:
https://riunet.upv.es/handle/10251/12473 [Gálvez Gabarda, B., 2011]

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https://www.rothoblaas.com/catalogues-rothoblaas

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CTE DB SE–A:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-A.pdf

Fig.44 Mediterráneo Pavilion construction photoraph [Bouzas, 2023]

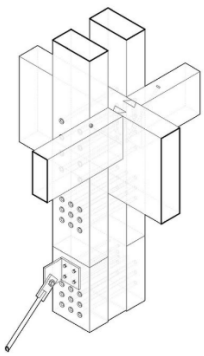

Fig.45 Mediterráneo Pavilion detai [Bouzas, 2023]

Fig.46 Mediterráneo Pavilion construction photoraph [Bouzas, 2023]

2.6.2 Disposition 2

Scope of Application:

Ideal for transverse connections in timber subject to tension. Suitable for 12 or 16 mm diameter bolts or threaded rods

Disassembled by simply unscrewing the bolt Suitable for temporary structures or those that can be disassembled and reassembled

[Rothoblaas, 2024]

Significant examples of the disassembly include Manuel Bouzas´ Mediterráneo Pavilion (Valencia) (fig 42, 43, 44) and Cabane 7L. (Rome). (fig 47, 48)

An example of assembly, disassembly, and reassembly in a different location, would be the winning proposal of AsIBs´ Ephemeral Bamboo Design competition 2025. (fig 46)

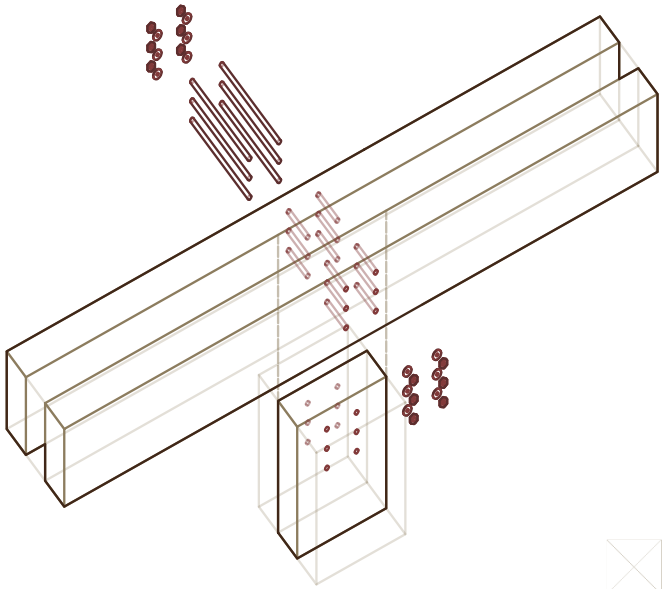

Fig.47 Own elaboration

Fastening Elements:

Fig.43 Rod, nuts and washers [Fixdex, 2025]

Calculation basis:

CTE DB SE-M:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:
https://riunet.upv.es/handle/10251/12473 [Gálvez Gabarda, B., 2011]

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https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-A.pdf

Fig.48 AsIBs´ Ephemeral Bamboo Design competition 2025, Own elaboration

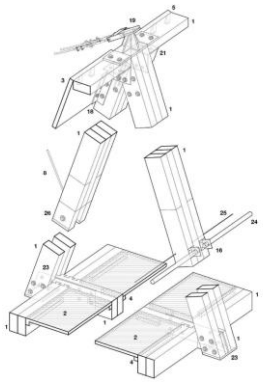

Fig.49 Mediterráneo Pavilion Axonometry [Bouzas, 2023]

Fig.50 Cabane 7L [Bouzas, 2024]

2.7 Dented Plate and Nails
2.7.1 Disposition 1

Scope of Application:

Generally, employed in trusses and frames. Shear Joints for timber walls and floors.

Can be applied to:

- *Solid Timber and Glulam*
- *Timber Frame*
- *CLT and LVL Panels*

[Rothoblaas, 2024]

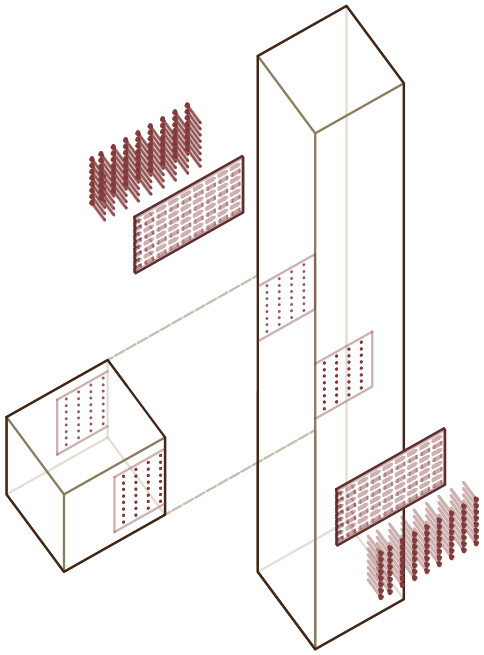

Fig.51 Own elaboration

Fastening Elements:

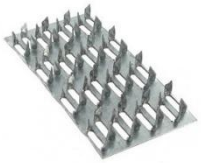

Fig.52 Dented plate
[MadeinChina, 2020]

Calculation basis:

CTE DB SE-M:

https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:

https://riunet.upv.es/handle/10251/12473
[Gálvez Gabarda, B., 2011]

UNE EN-338 and UNE EN-1194

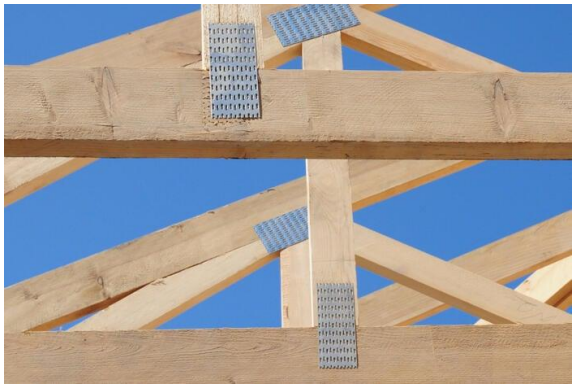

Fig.53 Joint photograph
[iStock / Getty Images Plus/Lex20]

Fig.54 Construction photograph
[Stock, 2014]

2.7.2 Disposition 2

Scope of Application:

Generally, employed in trusses and frames. Shear Joints for timber walls and floors.

Can be applied to:

- *Solid Timber and Glulam*
- *Timber Frame*
- *CLT and LVL Panels*

[Rothoblaas, 2024]

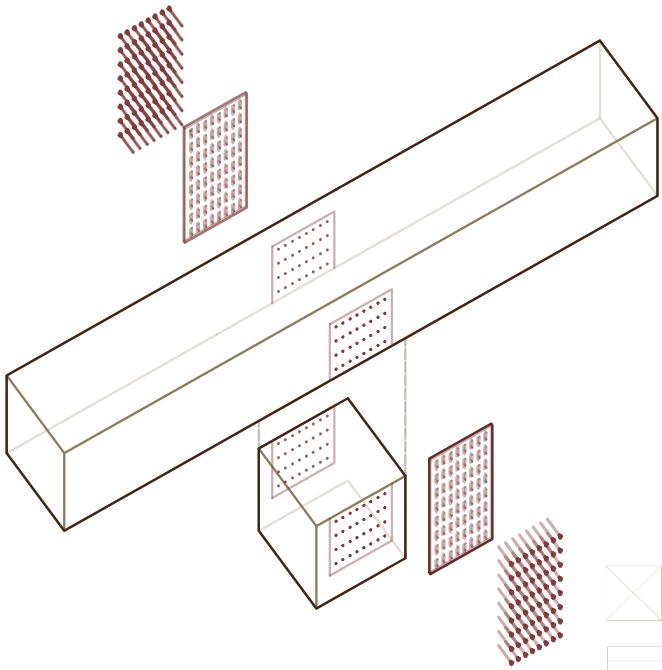

Fig.55 Own elaboration

Fastening Elements:

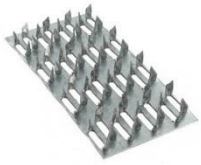

Fig.52 Dented plate
[MadeinChina, 2020]

Calculation basis:

CTE DB SE-M:

https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:

https://riunet.upv.es/handle/10251/12473
[Gálvez Gabarda, B., 2011]

UNE EN-338 and UNE EN-1194

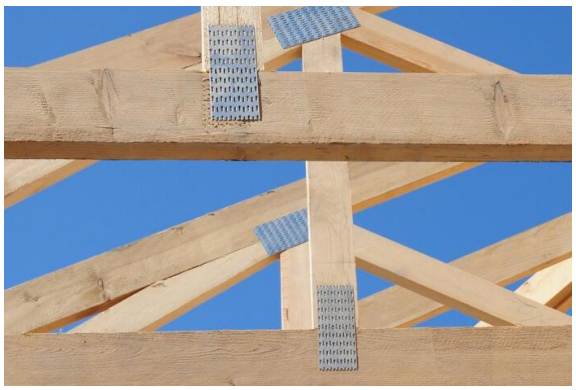

Fig.53 Joint photograph
[iStock / Getty Images Plus/Lex20]

Fig.56 Joint photograph
[Westbrook, 2013]

2.8 T – Joint Piece
2.8.1 Disposition 1

Scope of Application:

Concealed joint for beams in timber-to-timber or timber-to-concrete configuration, suitable for roofs, floors and medium-sized post-and beam constructions Use also outdoors in non-aggressive environments

Can be applied to:

- *Solid Timber Softwood and Hardwood*
- *Glulam and LVL*

[Rothoblaas, 2024]

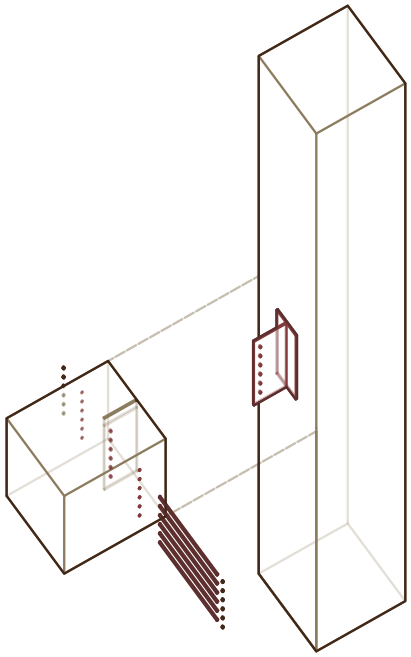

Fig.57 Own elaboration

Fastening Elements:

Fig.58 Alumidi concealed bracket [Rothoblaas, 2024]

Calculation basis:

CTE DB SE-M:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:
https://riunet.upv.es/handle/10251/12473 [Gálvez Gabarda, B., 2011]

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CTE DB SE–A:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-A.pdf

Fig.59 Construction photograph [Waugh Thistleton Architects, Dalston Works, 2025]

Fig.60 Joint photograph [Xiaofu, 2019]

2.8.2 Disposition 2

Scope of Application:

Concealed joint for beams in timber-to-timber or timber-to-concrete configuration, suitable for roofs, floors and medium-sized post-and beam constructions Use also outdoors in non-aggressive environments

Can be applied to:

- *Solid Timber Softwood and Hardwood*
- *Glulam and LVL*

[Rothoblaas, 2024]

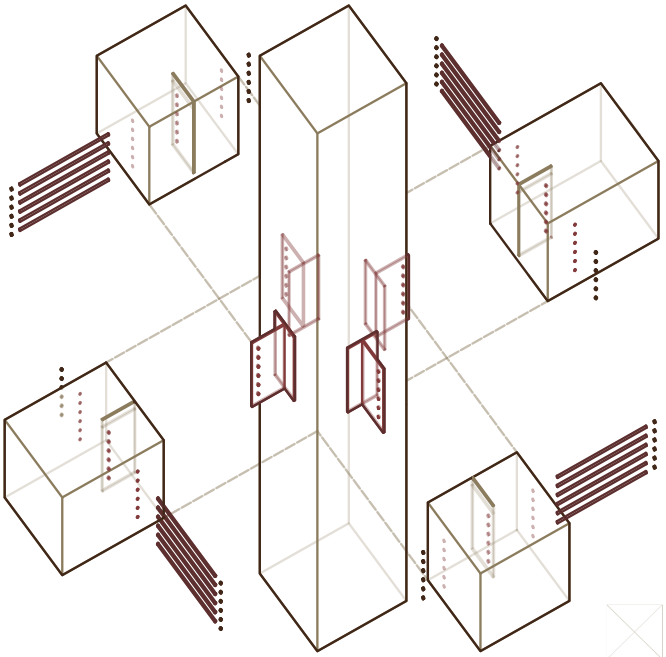

Fig.61 Own elaboration

Fastening Elements:

Fig.58 Alumidi concealed bracket [Rothoblaas, 2024]

Calculation basis:

CTE DB SE-M:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:
https://riunet.upv.es/handle/10251/12473 [Gálvez Gabarda, B., 2011]

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https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-A.pdf

Fig.62 Construction photograph [Azalea UPV, 2022]

Fig.63 Joint photograph [BE-ECO Srl, 2015]

2.9 Hook Piece
2.9.1 Disposition 1

Scope of Application:

Concealed beam joint in timber-to-timber configuration, suitable for medium-sized structures, floors and roofs Resistant outdoors, with the coated EVO version also in ag gressive environments

Can be applied to:

- *Solid Timber Softwood and Hardwood*
- *Glulam and LVL*

[Rothoblaas, 2024]

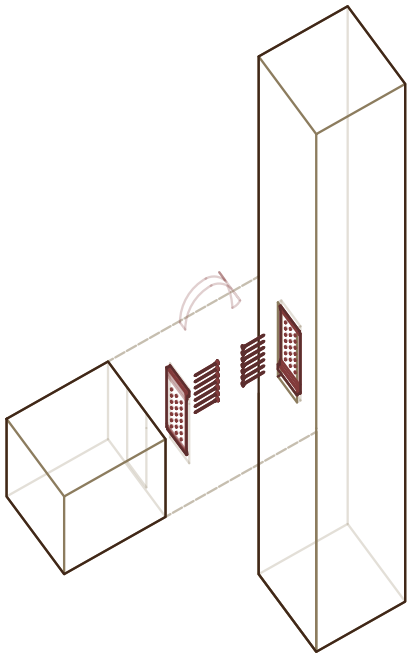

Fig.64 Own elaboration

Fastening Elements:

Fig.65 Lock T MIDI, concealed connector [Rothoblaas, 2024]

Calculation basis:

CTE DB SE-M:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:
https://riunet.upv.es/handle/10251/12473 [Gálvez Gabarda, B., 2011]

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UNE EN-338 and UNE EN-1194

Fig.66 Lock T MIDI, locked in place [Rothoblaas, 2024]

Fig.67 Lock T MIDI, fastened [Rothoblaas, 2024]

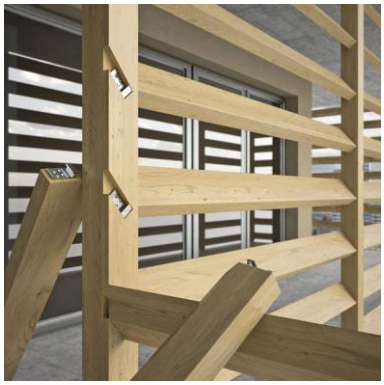

Fig.68 Lock T MIDI, inclined joint [Rothoblaas, 2024]

2.9.2 Disposition 2

Scope of Application:

Concealed beam joint in timber-to-timber configuration, suitable for medium-sized structures, floors and roofs Resistant outdoors, with the coated EVO version also in ag gressive environments

Can be applied to:

- *Solid Timber Softwood and Hardwood*
- *Glulam and LVL*

[Rothoblaas, 2024]

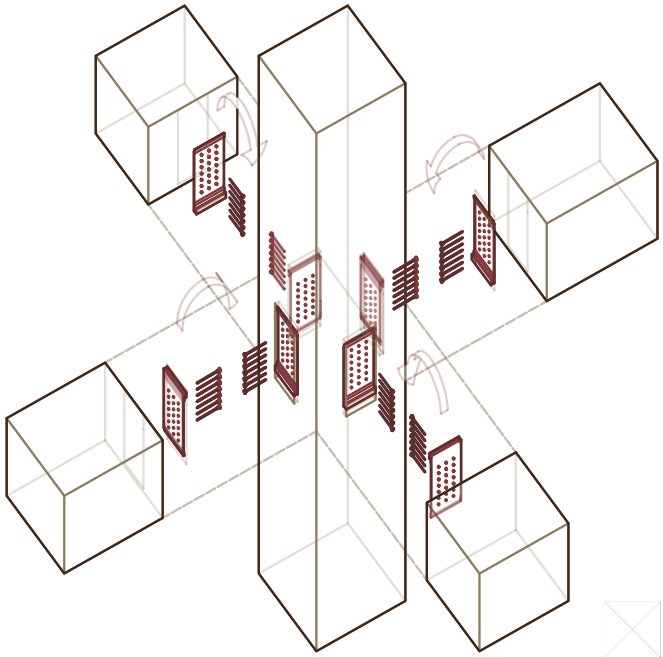

Fig.69 Own elaboration

Fastening Elements:

Fig.65 Lock T MIDI, concealed connector [Rothoblaas, 2024]

Calculation basis:

CTE DB SE-M:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:
https://riunet.upv.es/handle/10251/12473 [Gálvez Gabarda, B., 2011]

Rothoblaas Plates and Connectors for Timber 2024:
https://www.rothoblaas.com/catalogues-rothoblaas

UNE EN-338 and UNE EN-1194

Fig.66 Lock T MIDI, locked in place [Rothoblaas, 2024]

Fig.67 Lock T MIDI, fastened [Rothoblaas, 2024]

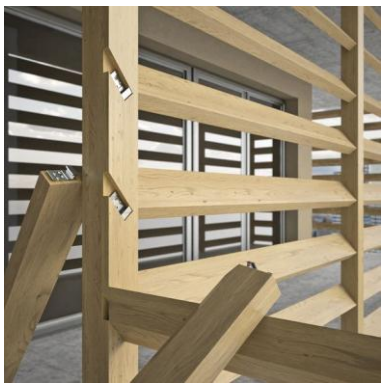

Fig.68 Lock T MIDI, inclined joint [Rothoblaas, 2024]

2.10 Dovetail Piece
2.10.1 Disposition 1

Scope of Application:

Concealed beam joint in timber-to-timber con f iguration, suitable for gazebos, floors or roofs

Can be applied to:

- *Solid Timber Softwood and Hardwood*
- *Glulam and LVL*

[Rothoblaas, 2024]

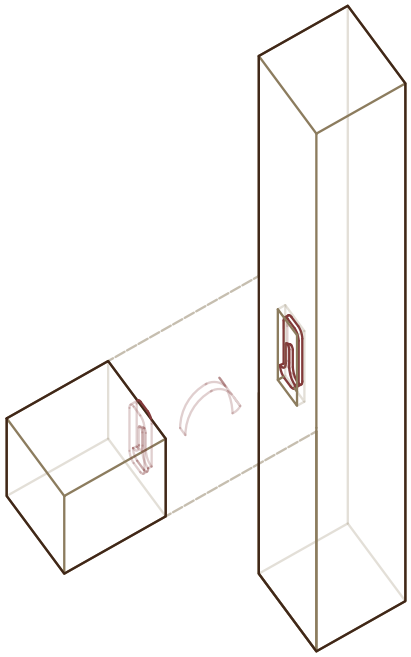

Fig.70 Own elaboration

Fastening Elements:

Fig.71 UVT dovetail connector [Rothoblaas, 2024]

Calculation basis:

CTE DB SE-M:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:
https://riunet.upv.es/handle/10251/12473 [Gálvez Gabarda, B., 2011]

Rothoblaas Plates and Connectors for Timber 2024:
https://www.rothoblaas.com/catalogues-rothoblaas

UNE EN-338 and UNE EN-1194

Fig.72 UVT timber to timber joint [Rothoblaas, 2024]

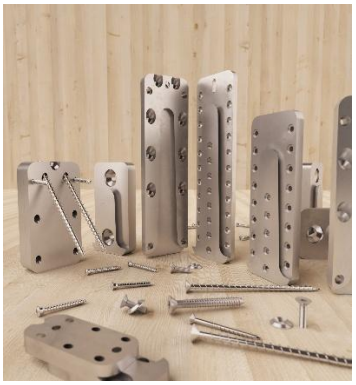

Fig.73 UVT derivates [Rothoblaas, 2024]

Fig.74 UVT timber to timber joint [Rothoblaas, 2024]

2.10.2 Disposition 2

Scope of Application:

Concealed beam joint in timber-to-timber con f iguration, suitable for gazebos, floors or roofs

Can be applied to:

- *Solid Timber Softwood and Hardwood*
- *Glulam and LVL*

[Rothoblaas, 2024]

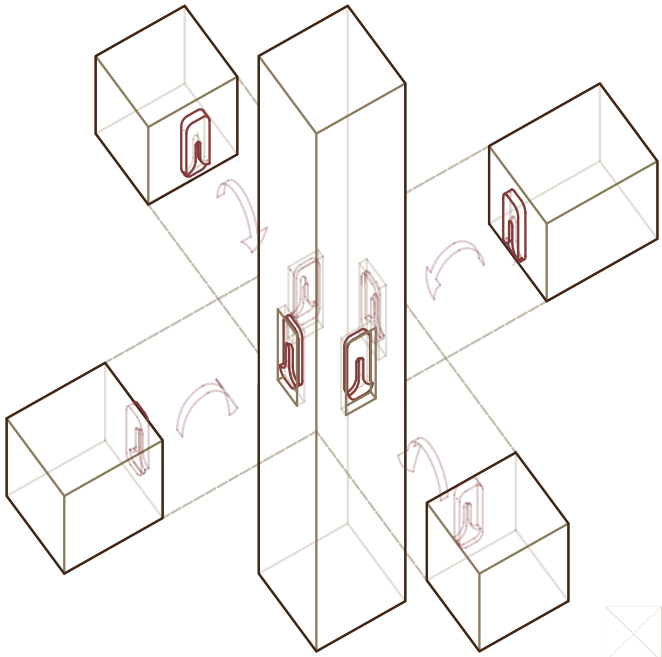

Fig.75 Own elaboration

Fastening Elements:

Fig.71 UVT dovetail connector [Rothoblaas, 2024]

Calculation basis:

CTE DB SE-M:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:
https://riunet.upv.es/handle/10251/12473 [Gálvez Gabarda, B., 2011]

Rothoblaas Plates and Connectors for Timber 2024:
https://www.rothoblaas.com/catalogues-rothoblaas

UNE EN-338 and UNE EN-1194

Fig.72 UVT timber to timber joint [Rothoblaas, 2024]

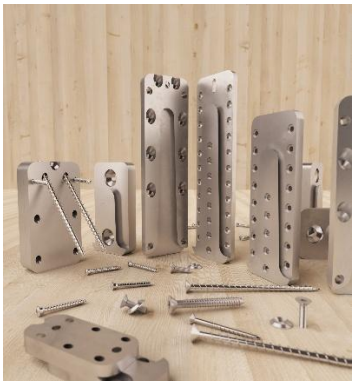

Fig.73 UVT derivates [Rothoblaas, 2024]

Fig.74 UVT timber to timber joint [Rothoblaas, 2024]

2.11 Hanger Piece
2.11.1 Disposition 1

Scope of Application:

Beam joint in timber-to-timber configuration, suitable for beams in floors and roofs

Can be applied to:

- *Solid Timber Softwood and Hardwood*
- *Glulam and LVL*

[Rothoblaas, 2024]

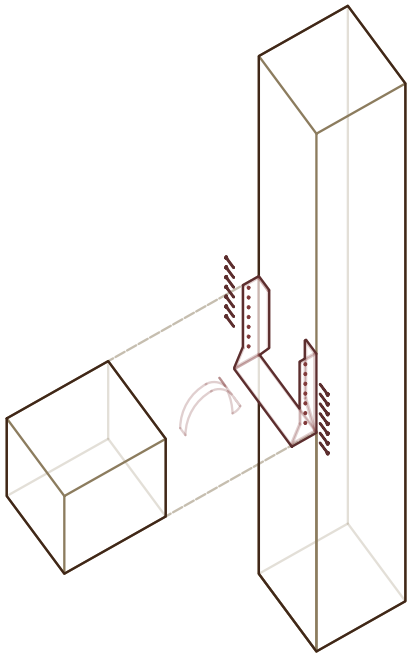

Fig.76 Own elaboration

Fastening Elements:

Fig.77 BSI metal hanger with internal wings[Rothoblaas, 2024]

Calculation basis:

CTE DB SE-M:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:
https://riunet.upv.es/handle/10251/12473 [Gálvez Gabarda, B., 2011]

Rothoblaas Plates and Connectors for Timber 2024:
https://www.rothoblaas.com/catalogues-rothoblaas

UNE EN-338 and UNE EN-1194

Fig.78 BSI timber to timber joint [Rothoblaas, 2024]

Fig.79 BSI timber to concrete joint [Rothoblaas, 2024]

2.11.2 Disposition 2

Scope of Application:

Beam joint in timber-to-timber configuration, suitable for beams in floors and roofs

Can be applied to:

- *Solid Timber Softwood and Hardwood*
- *Glulam and LVL*

[Rothoblaas, 2024]

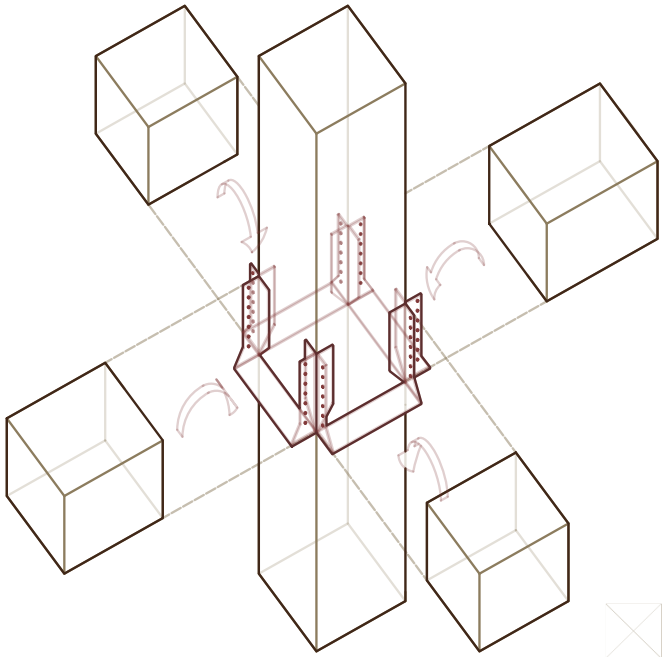

Fig.80 Own elaboration

Fastening Elements:

Fig.77 BSI metal hanger with internal wings[Rothoblaas, 2024]

Calculation basis:

CTE DB SE-M:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:
https://riunet.upv.es/handle/10251/12473 [Gálvez Gabarda, B., 2011]

Rothoblaas Plates and Connectors for Timber 2024:
https://www.rothoblaas.com/catalogues-rothoblaas

UNE EN-338 and UNE EN-1194

Fig.78 BSI timber to timber joint [Rothoblaas, 2024]

Fig.79 Timber to concrete joint [Sobrico, 2025]

2.12 Steel Slings [Project (Un)Build]

2.12.1 Disposition 1

Quick-Search Table

Case Study Description:

"Inspired by bamboo lashing techniques, Project (Un)Build uses strapping as a non-penetrative assembly method, facilitating easy disassembly while maintaining material integrity. The system envisions a wide range of applications across varying scales—wood-framed houses, office partitions, temporary shelters, outdoor pavilions, exhibition walls, and even furniture. It can also be adapted to join various types of dimensional lumber and engineered wood products."

[He, 2024]

Back in November 2024, we ran some preliminary load tests on our strapped wood joints. This setup held up to 2 tons of vertical static load before any visible deformation"

[Project (Un)Build, 2025]

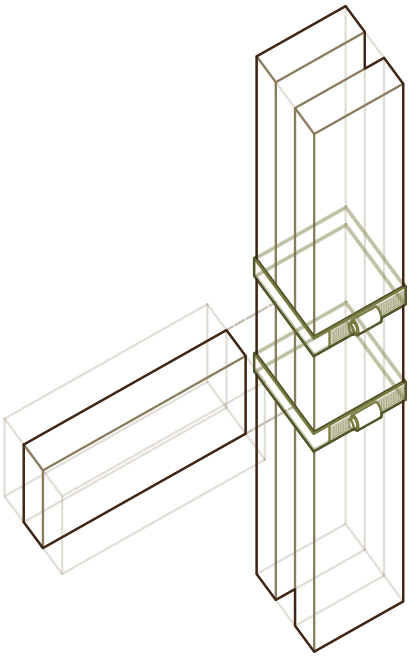

Fig.81 Own elaboration

Fastening Elements:

Fig.82 Fastening demonstration detail [Project (Un)Build, 2025]

Calculation basis:

CTE DB SE-M:

https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:

https://riunet.upv.es/handle/10251/12473
[Gálvez Gabarda, B., 2011]

UNE EN-338 and UNE EN-1194

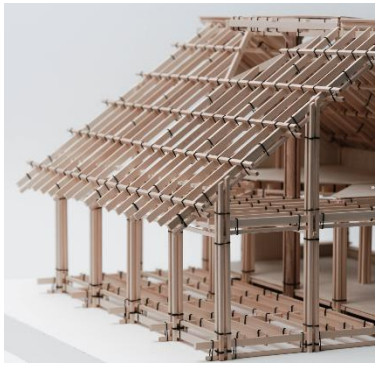

Fig.83 Model photograph [Project (Un)Build, 2025]

Fig.84 Stress test [Project (Un)Build, 2025]

Fig.85 Fastening demonstration details [Project (Un)Build, 2025]

2.12.2 Disposition 2

Case Study Description:

"Inspired by bamboo lashing techniques, Project (Un)Build uses strapping as a non-penetrative assembly method, facilitating easy disassembly while maintaining material integrity. The system envisions a wide range of applications across varying scales—wood-framed houses, office partitions, temporary shelters, outdoor pavilions, exhibition walls, and even furniture. It can also be adapted to join various types of dimensional lumber and engineered wood products."

[He, 2024]

Back in November 2024, we ran some preliminary load tests on our strapped wood joints. This setup held up to 2 tons of vertical static load before any visible deformation"

[Project (Un)Build, 2025]

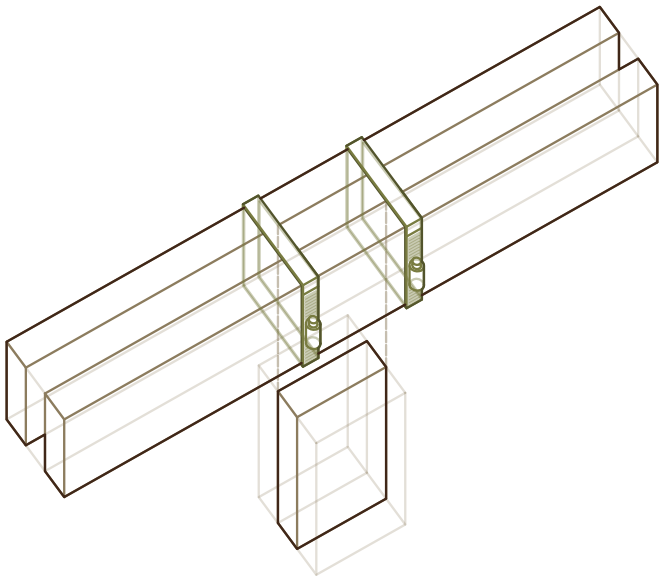

Fig.86 Own elaboration

Fastening Elements:

Fig.82 Fastening demonstration detail [Project (Un)Build, 2025]

Calculation basis:

CTE DB SE-M:

https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:

https://riunet.upv.es/handle/10251/12473
[Gálvez Gabarda, B., 2011]

UNE EN-338 and UNE EN-1194

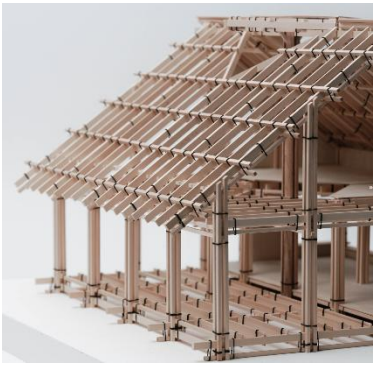

Fig.83 Model Photograph
[Project (Un)Build, 2025]

Fig.84 Stress test
[Project (Un)Build, 2025]

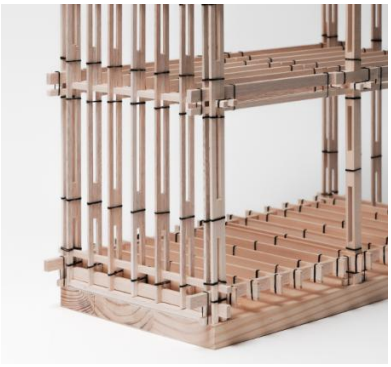

Fig.87 Model Photograph
[Project (Un)Build, 2025]

2.12.3 Disposition 3

Quick-Search Table

Case Study Description:

"Inspired by bamboo lashing techniques, Project (Un)Build uses strapping as a non-penetrative assembly method, facilitating easy disassembly while maintaining material integrity. The system envisions a wide range of applications across varying scales—wood-framed houses, office partitions, temporary shelters, outdoor pavilions, exhibition walls, and even furniture. It can also be adapted to join various types of dimensional lumber and engineered wood products."

[He, 2024]

Back in November 2024, we ran some preliminary load tests on our strapped wood joints. This setup held up to 2 tons of vertical static load before any visible deformation"

[Project (Un)Build, 2025]

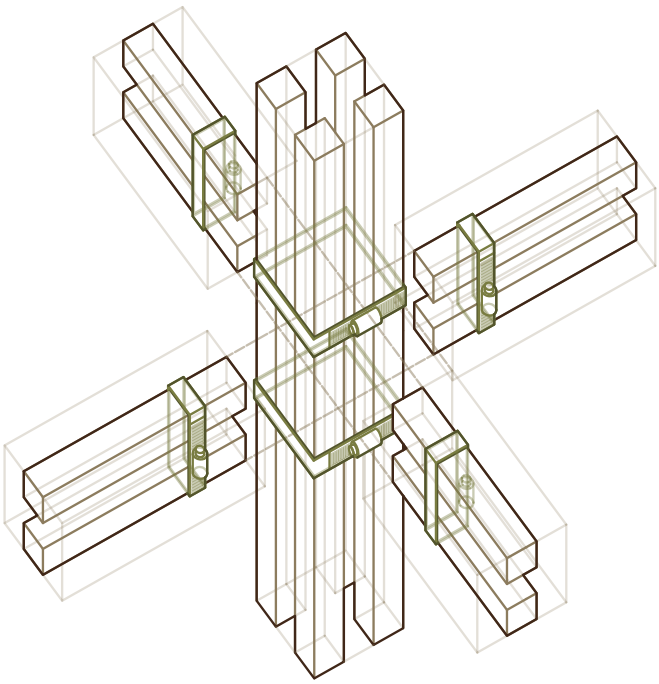

Fig.88 Own elaboration

Fastening Elements:

Fig.82 Fastening demonstration detail [Project (Un)Build, 2025]

Calculation basis:

CTE DB SE-M:

https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:

https://riunet.upv.es/handle/10251/12473
[Gálvez Gabarda, B., 2011]

UNE EN-338 and UNE EN-1194

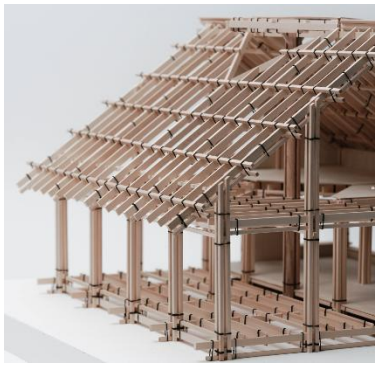

Fig.83 Model Photograph [Project (Un)Build, 2025]

Fig.89 Prototype detail [Project (Un)Build, 2025]

Fig.90 Model Photograph [Project (Un)Build, 2025]

2.13 Rod, Nut, Washer and Plate [Nest-We-Grow]

2.13.1 Disposition 1

Case Study Description:

"...We also focused on a heavy timber construction technique coming from the US, which uses large sections of wood. In Japan this translated to the composite column, which uses smaller pieces of wood to generate a larger column. It took considerable effort to identify a way to join materials, which was influenced by both local carpentry practices and the Japanese material market."

Text description provided by the architects

[Kengo Kuma & Associates + College of Environmental Design UC Berkeley, 2014]

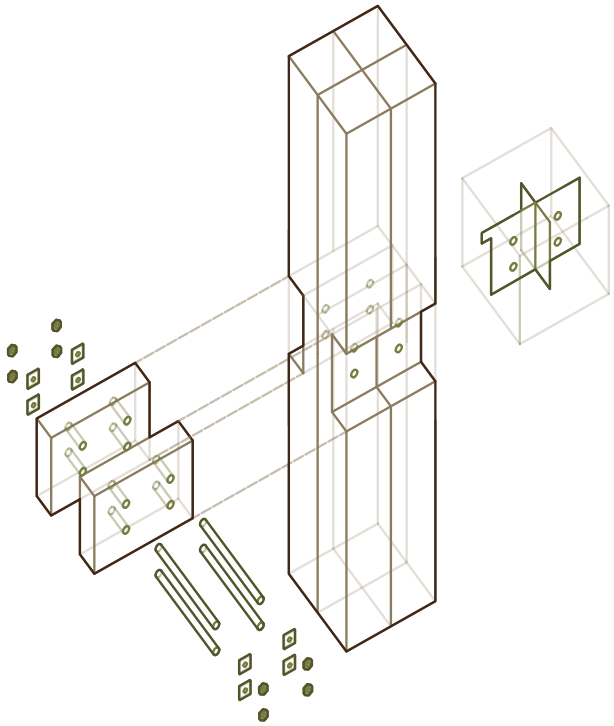

Fig.91 Own elaboration

Fastening Elements:

Fig.43 Rod, nuts and washers [Fixdex, 2025]

Calculation basis:

CTE DB SE-M:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:
https://riunet.upv.es/handle/10251/12473 [Gálvez Gabarda, B., 2011]

Rothoblaas Plates and Connectors for Timber 2024:
https://www.rothoblaas.com/catalogues-rothoblaas

UNE EN-338 and UNE EN-1194

CTE DB SE–A:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-A.pdf

Fig.92 Interior – exterior photograph [Shinkenchiku-sha, 2014]

Fig.93 Exterior photograph [Shinkenchiku-sha, 2014]

Fig.94 Detail photograph [Shinkenchiku-sha, 2014]

2.13.2 Disposition 2

Quick-Search Table

Case Study Description:

"...We also focused on a heavy timber construction technique coming from the US, which uses large sections of wood. In Japan this translated to the composite column, which uses smaller pieces of wood to generate a larger column. It took considerable effort to identify a way to join materials, which was influenced by both local carpentry practices and the Japanese material market."

Text description provided by the architects

[Kengo Kuma & Associates + College of Environmental Design UC Berkeley, 2014]

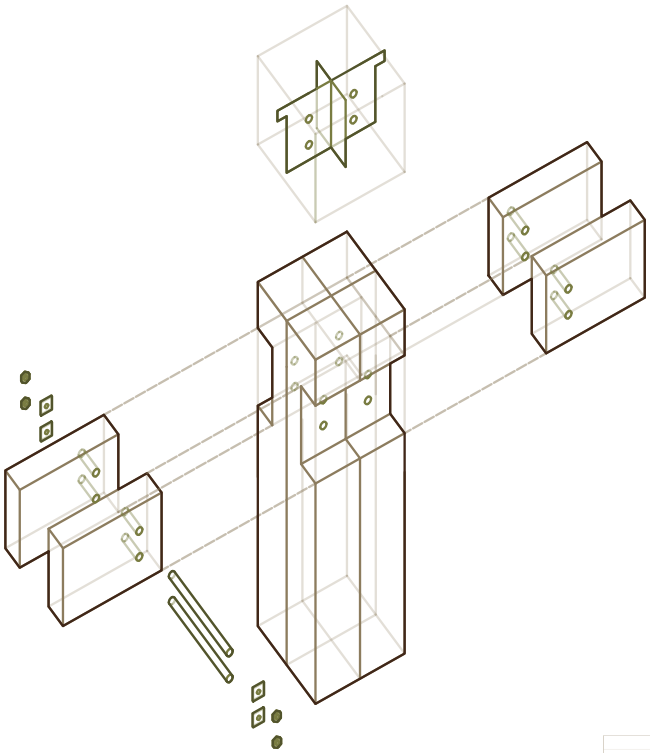

Fig.95 Own elaboration

Fastening Elements:

Fig.43 Rod, nuts and washers [Fixdex, 2025]

Calculation basis:

CTE DB SE-M:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:
https://riunet.upv.es/handle/10251/12473 [Gálvez Gabarda, B., 2011]

Rothoblaas Plates and Connectors for Timber 2024:
https://www.rothoblaas.com/catalogues-rothoblaas

UNE EN-338 and UNE EN-1194

CTE DB SE-A:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-A.pdf

Fig.96 Interior photograph [Shinkenchiku-sha, 2014]

Fig.97 Detail photograph during construction [UC Berkeley CED graduate team, 2014]

Fig.98 Photograph during construction [UC Berkeley CED graduate team, 2014]

2.13.3 Disposition 3

Case Study Description:

"...We also focused on a heavy timber construction technique coming from the US, which uses large sections of wood. In Japan this translated to the composite column, which uses smaller pieces of wood to generate a larger column. It took considerable effort to identify a way to join materials, which was influenced by both local carpentry practices and the Japanese material market."

Text description provided by the architects

[Kengo Kuma & Associates + College of Environmental Design UC Berkeley, 2014]

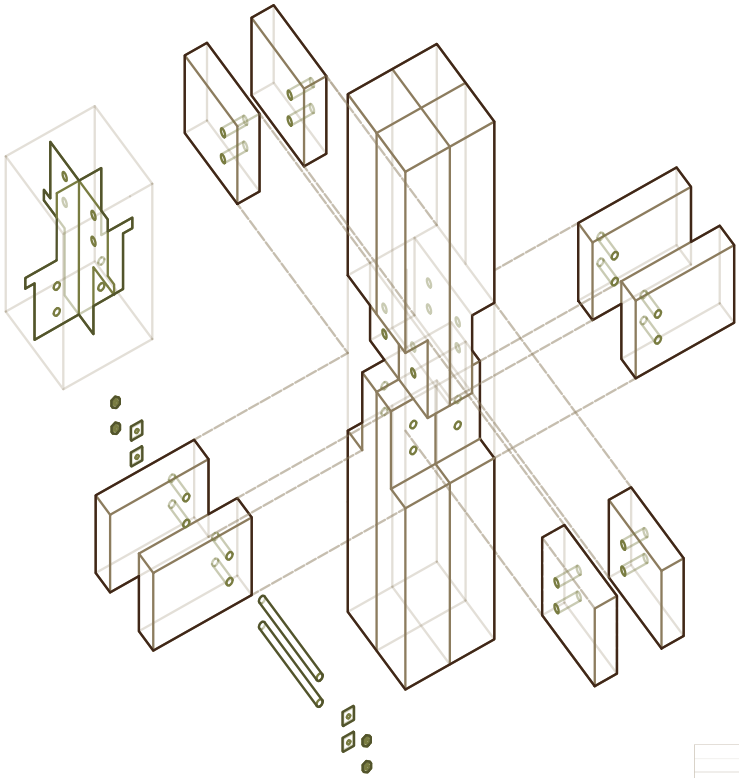

Fig.99 Own elaboration

Fastening Elements:

Fig.43 Rod, nuts and washers [Fixdex, 2025]

Calculation basis:

CTE DB SE-M:
https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-M.pdf

Calculation Spreadsheet with disposition limitations:
https://riunet.upv.es/handle/10251/12473 [Gálvez Gabarda, B., 2011]

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UNE EN-338 and UNE EN-1194

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https://www.codigotecnico.org/pdf/Documentos/SE/DBSE-A.pdf

Fig.96 Interior photography [Shinkenchiku-sha, 2014]

Fig.97 Detail photography during construction [UC Berkeley CED graduate team, 2014]

Fig.100 Photography during construction [UC Berkeley CED graduate team, 2014]

3. Conclusion

The work carried out in this document, consisting of the compilation of recent publications related to structural timber joints and their classification, has allowed for the development of a rigorous catalogue of timber joints.

The design of the catalogue implemented a visual system that includes color, markers, a table layout, and a unified and attractive graphic style. This design enables quick and intuitive cross-referencing among the elements, facilitating inquiries and thereby enhancing its use and understanding.

Furthermore, the relevance of considering the degree of chemical and physical alterations that timber elements undergo during the joining process has been emphasized from the perspective of life cycle assessment. In this regard, it is concluded that figures 81, 86, and 88 are optimal for downcycling into pellets, as the timber used is free of adhesives and its fastening elements are easy to completely remove.

Finally, the following further steps in this line of investigation are proposed:

- Analysis of additional contemporary case study joints, such as concrete nodes in timber-to-timber joints.
- A widening of the catalogues scope, including joints on different supports, such as concrete or masonry walls.
- A deeper definition of each joints´ calculations process.

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Fig.2.1
[Eliassen et all, 2019]
Eliassen, A. R., Faanes, S., & Bohne, R. A. (2019). Comparative LCA of a concrete and steel apartment building and a cross laminated timber apartment building. *IOP Conference Series. Earth and Environmental Science*, *323*(1), 012017. https://iopscience.iop.org/article/10.1088/1755-1315/323/1/012017/pdf

Fig.2.2
[Eliassen et all, 2019]
Eliassen, A. R., Faanes, S., & Bohne, R. A. (2019). Comparative LCA of a concrete and steel apartment building and a cross laminated timber apartment building. *IOP Conference Series. Earth and Environmental Science*, *323*(1), 012017. https://iopscience.iop.org/article/10.1088/1755-1315/323/1/012017/pdf

Fig.3
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https://mb-ae.es/Common-Land-Common-Lives-Cambridge-2022

Fig.4
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Fig.5.1
IVE – Base de Datos de Construcción
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Fig.5.2
IVE – Base de Datos de Construcción
https://www.five.es/costes-de-construccion/

Fig.5.3
IVE – Base de Datos de Construcción
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Fig.6
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Gu, H., Liang, S., & Bergman, R. (2020). Comparison of building construction and life-cycle cost for a high-rise mass timber building with its concrete alternative. *Forest Products Journal*, *70*(4), 482–492.
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Fig.7.1
Own elaboration.

Fig.7.2
Own elaboration

Fig.7.3
Own elaboration.

Fig.8.1
Own elaboration.

Fig.8.2
Own elaboration.

Fig.9
Own elaboration.

Fig.10.1
Own elaboration.

Fig.10.2

Own elaboration.

Fig.11
Own elaboration.

Fig.12
[UK OAK, 2025]
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Fig.13
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Fig.14
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