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THE ENHANCEMENT OF LOCAL RESOURCES: RESEARCH, TEACHING AND EXPERIMENTATIONS IN L'AQUILA+

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Highlights

The paper illustrates how to valorize the territory of L'Aquila through the analysis of the climatic and material context and the identification of local resources (including waste), the management of selective demolition, the identification of appropriate technology, and the performance of materials/components. A path of research, training of construction sector operators and experimentations, through the design of temporary modules that reuse waste materials from post-seismic reconstruction in L'Aquila. The paper highlights how sustainability in the building process also passes through the training by the university of technicians who, after completing their studies, will work in companies.

Abstract

The construction sector has a major impact on current environmental issues. Through cost-effectiveness, it is possible to encourage construction sector operators to trigger voluntary environmental protection mechanisms. The use of local resources (including waste materials) is one of the possible strategies but requires specific and interdisciplinary training involving many aspects, including context analysis, demolition management, durability and reversibility control, and the ability to identify the performance of the construction system. The paper illustrates a path of research, teaching and experimentations concluded with the design and realization in self-construction of temporary modules, reusing waste materials from post-seismic reconstruction in L'Aquila.

Keywords

Reuse, Self-construction, Waste materials, Economic development, Sustainability.

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1. COST-EFFECTIVENESS AS A TRIGGER FOR ENVIRONMENTAL PROTECTION

"Whatever you do in the world, you do it to yourselves." This is the slogan of a global campaign on environmental protection launched by Advertisers Without Borders that well expresses the correlation between human action and direct and indirect effects on the environment. Think that in these months (January-May 2020), the reduction of human activities and in particular of mobility worldwide, due to the COVID19 pandemic, has produced a cascade reduction in the concentration of nitrogen dioxide with an improvement in air quality [1] (Fig. 1).

Environmental sustainability depends on the actions that each individual takes in his or her daily life, choices related to private and working life (number and mode of travel, choice of workplace, type and mode of use of resources such as water and electricity, food and consumer goods choices, etc.). The choices are, however, conditioned by each individual's knowledge of reality, according to the principle that "everyone sees what he knows" (Bruno Munari). Environmental awareness campaigns and, more specifically, the training of operators in the various sectors are therefore aimed at broadening knowledge and skills in order to allow a better understanding of reality (cause and effect) and to encourage a more responsible attitude.

an economic advantage. Taking a leap of scale and considering the industrial processes (which have always been accused of a great responsibility towards environmental pollution), one example of industrial symbiosis [3] is the industrial district of Kalundborg located in Denmark [4]. Since 1972 it has progressively developed thanks to the economic advantages deriving from the sharing and circularity of water, energy, and material cycles and which allows environmental advantages in terms of saving resources and avoided emissions.

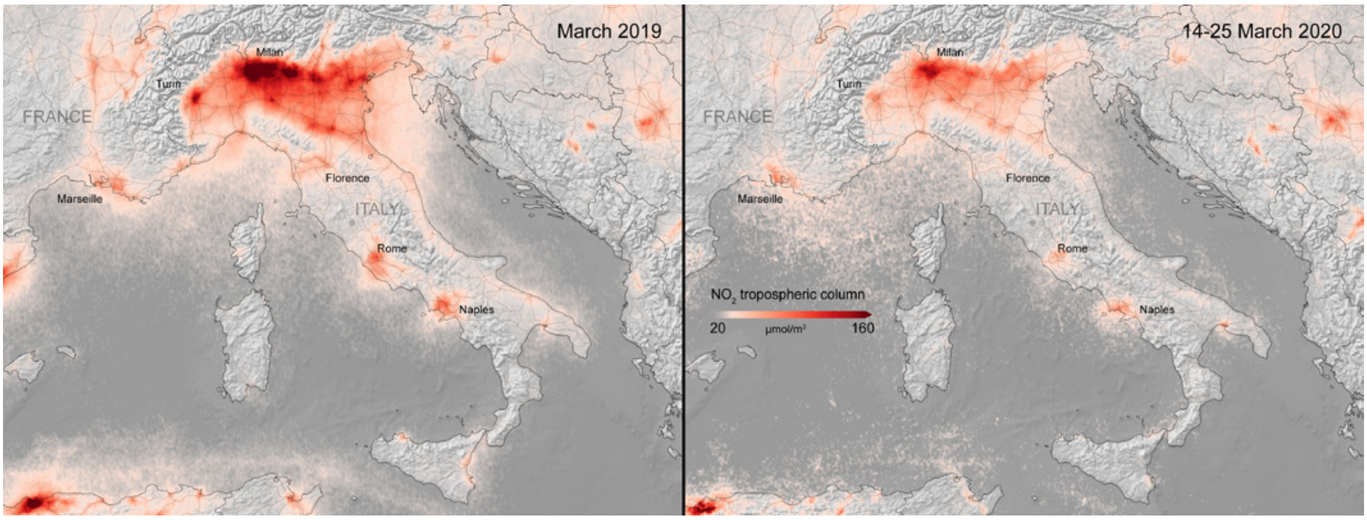

Fig. 1. *Nitrogen dioxide concentration over Italy – ESA European Space Agency.*

The assumption of responsibility clashes, however, with the perception of the shift in time of the effects of today's action, which sometimes leads to consider the existing environmental problem, but not necessarily conditioning. Suffice it to say that the study of the causes of global warming at government level began in 1988 with the formation of the scientific forum Intergovernmental Panel on Climate Change (IPCC), but operationally the Kyoto Protocol (1997) and the Paris Accord (2015) have not produced the desired effects [2]. The need to overcome environmental problems often does not seem to be a sufficient motivation to trigger responsible action by the community. In contrast, when an environmental benefit is associated with economic advantage, voluntary environmental protection mechanisms are developed. An example related to everyday life is represented by the plastic bottle compactors, which in return for the separate collection of plastic bottles by the user, give him/her a voucher and thus

According to a report prepared by IEA and UNEP and presented at COP24 (2018), buildings account for about 40% of global greenhouse gas emissions, 36% of total energy consumption, and are responsible for 50% of raw material extraction and 1/3 of drinking water consumption. Given the environmental importance of the construction sector, it follows the need to identify actions that they are economically advantageous, produce a cascading environmental benefit. By analyzing the life cycle of the building (construction, use, demolition) for each phase, it is possible to identify actions that bring both economic and environmental benefits. The use phase of the building is all the more convenient from an economic and environmental point of view the more energy-efficient the building is and the more it has been designed and built taking the climate context into account. In the construction and demolition phases of the building, on the other hand, convenience is linked to the materials and construction systems used, a consequence of the availability in the territorial context. The more the materials and chosen building systems allow to trigger local cyclical processes by optimizing grey energy (associated with the product during its entire life cycle), the more an economic and environmental advantage is obtained. The increase, in fact, of the life span of any consumer goods allows decreasing the incidence that in a given period of time (annual, monthly, etc.) the production of that object has had on the environment. In the construction and demolition phases, the construction method used and, in particular, the energy contribution of the means and machinery used also has an impact. In this regard, the use of construction systems in which assembly/disassembly is easy and quick allows the use of unskilled labor and the construction of the building in self-construction. The result is a reduction in construction costs due both to the reduction in labor costs and to the prevalent use of manual equipment (more suitable for unskilled labor), also obtaining an environmental advantage.

2. THE NEED FOR SPECIFIC TRAINING

The environmental and economic optimization of the building process, in all phases of the life cycle, is linked to the construction equipment and related materials. The suitable technology (right tech) is opposed to the choice a priori of low-tech or high tech, identifying the most suitable technology after the analysis of the territorial context and the performance required by the building. The choice of a suitable technology allows in the use phase to obtain appropriate performances and to guarantee the environmental comfort and, in the construction and demolition phases, to safeguard resources, especially materials. The identification of suitable technology is an operation that requires, however, specific, and complex training that involves many interdisciplinary aspects.

2.1. THE TERRITORIAL CONTEXT: CLIMATE AND MATERIALS

The territorial context can be divided into two macro-categories: the climatic context and the "material context". The analysis of the climatic context makes it possible to identify the microclimate in which the building is located (temperature, sunshine, ventilation, rainfall, etc.) in order to define the performance that must be achieved by the building according to its intended use with the aim of ensuring environmental comfort [5]. The "material context" identifies, instead, the characteristics of a given territory in terms of resource availability within a specific mileage. The analysis of the material context makes it possible to define in a local dimension [6, 7] what resources are available. Among the latter, must be considered local materials that allow the environmentally friendly production of components and waste materials that can be sent to a new life cycle. Operationally it is necessary to carry out a mapping of the territory identifying for each resource the distance from the place where the building is located. In some territorial areas, online platforms/markets have been created where it is possible to identify the availability of materials at a given time [8, 9].

2.2. DEMOLITION MANAGEMENT

Among the local resources, waste, materials/components that have already undergone one or more life cycles, but which have sufficient residual performance to be reused again, are particularly important. Among the waste materials that can be used in the building industry, there are both materials from other sectors (tires, pallets, bottles, etc.) and materials from the building industry (tiles, wooden beams, doors, and windows, etc.). In the latter case, the materials are actually reusable only if they have remained intact during demolition operations. The demolition of the building must, therefore, be carried out selectively: the building must be progressively demolished starting from the components which, compared to the construction method, have greater integrity (radiators, tiles, fixtures, railings, etc.) to the components which have less integrity (wet partitions, screeds, etc.) [10]. Selective demolition requires a thorough knowledge of demolition techniques, machinery/equipment, and the building [11]. The construction site must be dimensioned and organized, considering different storage for each product fraction and, at the same time, organizing its transport. The technician must have the skills to identify the residual and potential performance of the materials making up the building and define the demolition plan according to the building's construction characteristics and in such a way as to guarantee the integrity only of the actually reusable components. Not being able to understand whether material is actually reusable entails the risk of additional work during demolition (in order to ensure the integrity of the component), which is not economically viable with subsequent reuse.

Moreover, the analysis of the territorial context is necessary to identify the end-of-life possibilities present in a given territory. The choices in the planning of selective demolition must, in fact, also be made on the basis of the distance of the processing, recycling, or disposal plants and the reuse possibilities present in the specific territory.

2.3. IDENTIFICATION OF RESIDUAL AND POTENTIAL PERFORMANCE OF LOCAL RESOURCES

Among the local resources, it is necessary to identify the materials that, combined with each other, enable the building to achieve performance that guarantees environmental comfort. The technician must be able to identify the residual performance of a given material/component and evaluate the various performances potentially achievable with possible reconditioning operations. In addition, it is essential to know the environmental and economic impact of each operation in order to assess whether its cost offsets the advantage obtained in terms of performance. If it is an economically viable operation, the possibilities and methods of reuse can be identified. Being able to identify the residual and potential performance of the materials/components individually and combined, means being able to define which construction elements can be derived from the local supply chain and which, instead, must be supplied outside the local context, in order to achieve the desired performance for building.

2.4. DURABILITY AND REVERSIBILITY: REQUIREMENTS TO BE DESIGNED

Among the requirements, durability is particularly important. In order to use local resources, including waste materials, it is necessary to know the durability of the individual components in relation to the time of use of the building. For example, in the design of a temporary building, it can also be used untreated wood elements as a finish, provided that their durability is not less than the time of use of the building. Conversely, in the design of a building with a useful life of 50 years, treated wood elements we can also use as a finish, with the intention of replacing them when due to degradation, their performances are lower than the minimum performances established for the building.

The durability of the components must also be assessed. The optimal condition would be to use materials/components that have the same durability coinciding with the time of use of the building, in order to dismantle the building and the components at the same time, making maximum use of the grey energy of each building element. Since this is a condition of impossible realization due to the diversified nature of the single materials which, thanks to their different characteristics, can combine to guarantee complex performances, it is necessary to foresee a maintenance plan, through which, during the time of use of the building, the construction system guarantees the achievement of the required performances [12].

The reversibility of the building allows advantages from an economic and environmental point of view. During use, facilitating maintenance operations, it is a prerequisite for durability control [13]. In the demolition phase, the reversibility makes it possible to divide the materials/components into homogeneous product fractions, starting each one at the most appropriate end-of-life scenario with respect to its residual performance. The type of connections between the building elements is the only factor that, by nature, conditions reversibility. In order for it to be possible to carry out backward the path that led to the construction of the building, the connections must be dry (bolting, screwing, seaming, nailing, etc.).

The design of reversibility also concerns the way in which the building is connected to the ground, allowing the protection of the soil, which is a vital and "fundamentally non-renewable" resource of the Earth. In 2017 in Italy, there was a land consumption of 15 hectares per day. Overall, Italian soil consumption is 23,062.5 square km [14].

3. RESEARCH, TEACHING, AND EXPERIMENTATIONS

The University of L'Aquila, in collaboration with other institutions (Universitat Politècnica de València, Ente Scuola Edile L'Aquila (CPT), ANCE Giovani L'Aquila, Filauro Foundation), has promoted an experience of experimentation and training of specialized technicians through the design and self-construction of temporary modules.

The analysis of the material context in L'Aquila has highlighted the availability within a narrow radius of 10 km of resources that can be used in construction (Fig. 2), both linked to territorial peculiarities such as wood, fibers linked to agriculture (straw), waste from the zootechnical industry (sheep wool) and to the current post-seismic reconstruction phase (rubble, pallets, materials deriving from selective demolition such as tiles, solid bricks, etc.). In particular, previous research [15] has highlighted the availability of a significant amount of waste resulting from the disassembly of safety systems including scaffolding, pallets, steel beams, etc., materials whose transport to landfill and disposal involves significant logistical, economic and environmental costs for the community [16, 17].

The training and experimental experience had the task of preparing in international context technicians who will work in the reconstruction in the crater of L'Aquila on how to transform such waste into an environmental and economic advantage, in a resource at no cost. The skills of specialized technicians can, in fact, make it possible, through their choices, the activation of a spontaneous reuse chain. The experience has been divided into three parts: theoretical, design, and self-construction.

3.1. THE THEORETICAL PART

The theoretical part allowed the technicians to learn the knowledge about the topics previously described,

Fig. 2. *Harvest map L'Aquila.*

Fig. 3. *Theoretical training (prof. Di Carlo), practical training (CPT L'Aquila) and field visit to the construction sites in the "red zone" in L'Aquila.*

through frontal lessons with experts in the sustainability field at the national and international level and, consequently, the direct contact with consolidated approaches and methods in different territorial contexts (Fig. 3). In order to identify the construction techniques and technologies used in the post-seismic reconstruction and to understand the implementation of virtuous practices related to the environmental sustainability of the construction site, the students visited some reconstruction sites located in the red zone of L'Aquila. The theoretical part was also fundamental to acquire knowledge about the characteristics and actual and potential performance of the available local materials to be used in the project.

3.2. THE PROJECT

The design part involved the students divided into groups led by tutors in the design of temporary modules to be used for different functions: an info-point, a bathing establishment for restricted contexts, a temporary residence, a space for music, a bike-sharing and an exhibition area. The functions have been hypothesized considering the possibility of using the temporary modules within a maximum mileage of 100 km (local dimension for the Ithaca Protocol) with respect to the place where the materials are found. The materials used in the projects derived exclusively from post-seismic reconstruction and were donated by ANCE Giovani L'Aquila and CPT L'Aquila. The students, in particular, interfaced with the system of innocent tubes, pallets, and wooden boards, with dimensional (and modular) characteristics already defined in advance. The presence of different modules required the students to think about the dimensional coordination of the components. The projects also had to comply with the reversibility requirement, and reasoning on durability control was carried out. The project deepening has reached a level of executive detail, necessary for the next phase of self-construction. For example, in the project concerning the bathing establishment

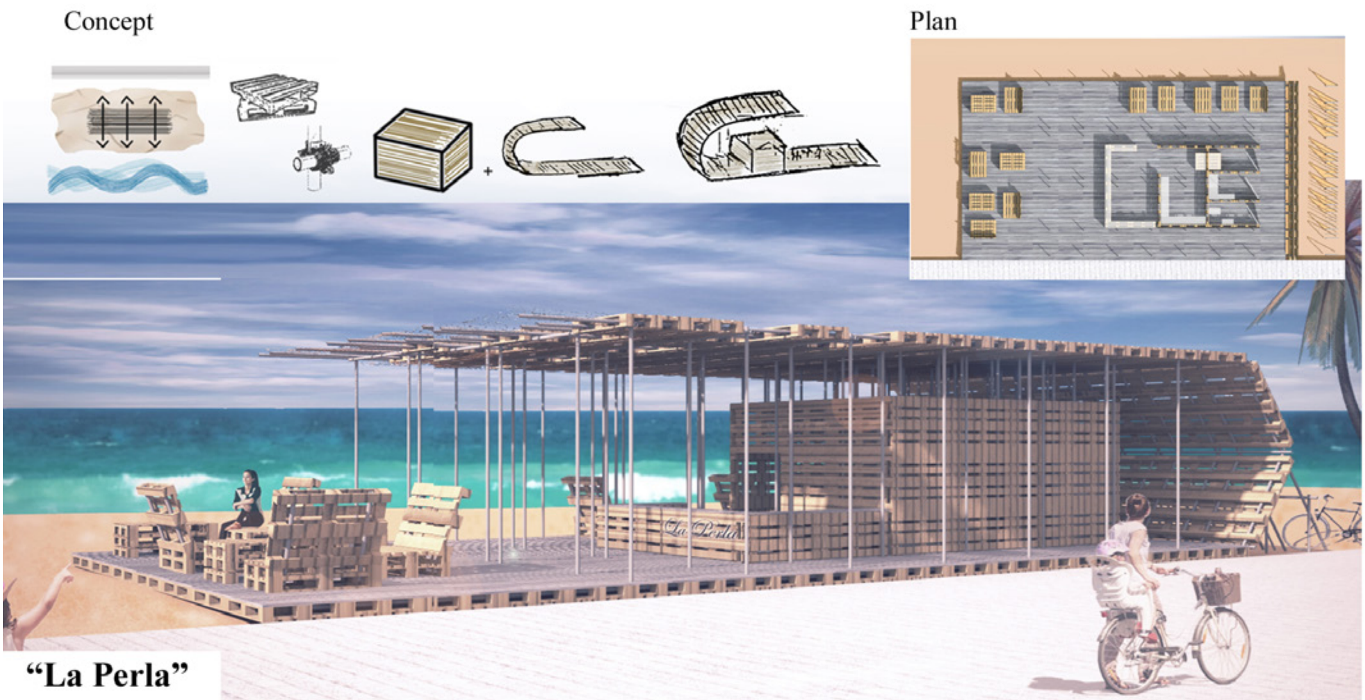

Fig. 4. *Design part. "La Perla" bathing establishment. Concept, plan, and render.*

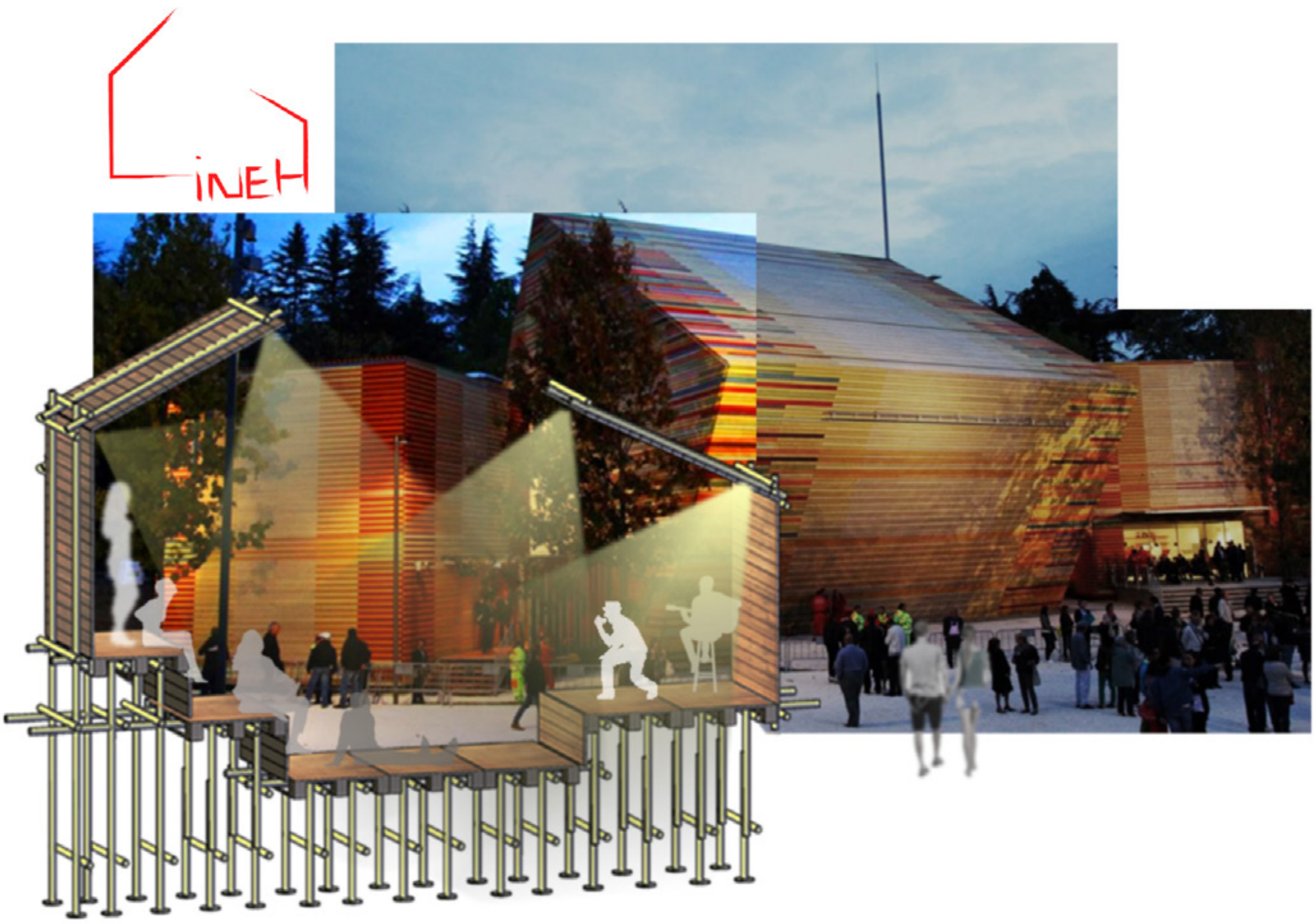

Fig. 5. *Design part. A temporary space for music. Render in the Castle Park, L'Aquila.*

for restricted contexts, called “La Perla “ (Fig. 4), the waste materials of the reconstruction were integrated with easily available waste materials such as ropes, canvas, and bottles. Attention to the intervention sustainability is also highlighted by sustainable mobility systems integration of such as bicycles into the building organism.

In the design of the music space (Fig. 5) for temporary summer installations, the value was given to the flexibility of the construction system and its ease and speed of modification, characteristics typical of systems traditionally used on sites such as pipes and joints.

3.3. THE SELF-CONSTRUCTION

The realization part involved the students guided by the tutors in the self-construction of their project (Fig. 6). This choice was a tool to make the students understand the construction techniques necessary for the realization of what they designed, to verify the operational and logistic difficulties related to the design choices and the construction times of unskilled labor. In the initial phase of self-construction, each group identified the construction phases, the materials needed and divided the tasks among the members of the group.

Each group also had to provide for the organization of the construction site, especially with regard to aspects related to the handling of materials and the availability of limited space for maneuvers also due to interference with neighboring groups operating in the same area.

The self-construction time was equal to two working days. It should be noted that, although these are temporary structures of medium complexity, no variations were made during the self-construction work, a sign of the effectiveness of the training that has ensured successful projects and studied with competence in detail.

4. CONCLUSIONS

The considerable impact of the construction sector on environmental issues requires specific skills in design and construction choices, such as to be able to manage and control the entire life cycle of the architectural organism. It is, therefore, necessary to provide interdisciplinary training for operators in the sector, first of all, technicians. Experience has shown that through specific training and comparison with international realities, it is possible to change the traditional design approach from the idea to the choice of materials/components in an experimental approach. The latter starts from the parallel analysis of the requirements necessary for the building and the resources and operational possibilities dictated by the territorial context (climatic and material) and identifies, based on them, a compatible project, and appropriate technology. It increases the degree of complexity of the project but also increases the sustainability of the intervention.

The realization of temporary modules in self-construction with reused materials has, moreover, carried out an action of sensitization of the local enterprises, with respect to the possibilities that the materials considered waste can offer with a direct economic advantage for the enterprise and environmental advantage for the community. The university, through training and research, has therefore been a vehicle of knowledge and awareness of the territorial context, which currently interfaces daily with post-seismic reconstruction.

A cascade phenomenon that started from research passed through training and arrived at companies, an operational arm on the territory that translates the needs of the client into architecture, mediating them with those of the community. Only through cooperation between universities and companies is it possible to apply the innovations deriving from research to the territory.

5. ATTRIBUTIONS

Stefania De Gregorio has conceived and structured the paper and had the managing supervision and the scientific coordination of the educational and experimental experience. Pierluigi De Berardinis and Luis Palmero have supervised the paper and had the scientific responsibility for the educational and experimental experience.

The figure 4 was elaborated by: tutor: Valentina Michini, students: Oscar Mico Cerdan, Marta Pezzi, Pablo Puchol Herreros, Federico Ratini, Nacho Romero Hernandez, Carlo Sciamanna. The figure 5 was elaborated by: tutor: Arianna Tanfoni, students: Daniela Cerasani, Adolfo M. Moltó Vidal, Jorge Moltó Vidal, Federica D’Orsogna, Laura Garribo Abalos, Sara Zaccaria.

Fig. 6. *Self-construction phases (tutor: S. Balassone, L. Capannolo, D. Di Donato, E. Laurini, V. Michini, A. Tanfoni, A. Tata).*

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