

Temporary systems after the earthquake in L'Aquila

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Abstract

After an earthquake, temporary structures play a key role in the immediate emergency and during the reconstruction. In the territory of L'Aquila, after the earthquake of the 6th April 2009, tents were used in the first emergency to provide immediate shelter to the population and prefabricated structures have been used later to accommodate the population during the longest stage of the reconstruction. But there is another type of temporariness too, linked to the securing of the damaged buildings and aimed to preserve the historical and artistic value and ensure the safety of road and workers during the reconstruction period. The secure systems use temporary devices, consisting mainly of tubular scaffoldings, multi-directional systems, systems in wood, systems with metal profiles and steel cables, polyester clamps. These systems are used interchangeably according to the function they perform, flexibility, time and cost of installation. During the reconstruction phase safety systems are disassembled, progressively generating an enormous amount of waste materials. For these materials it has not been planned a second lifecycle and disposal has a high environmental impact. It is proposed the reuse of these waste materials at zero distance. The purpose is to obtain environmental, logistic and economic advantages. Reuse provides a function change under the temporary, from safety systems to building systems, aimed to the construction of temporary structures, which, in the reconstruction phase, simplify site organization and, in the post-reconstruction phase, restructure public and private spaces.

Keywords: temporary systems, earthquake, reconstruction, secure systems, waste materials, reuse, lifecycle.



1 Temporariness in the post-earthquake in L'Aquila

On the 6th April 2009, at 3.32 am, an earthquake of magnitude 5.8 on the Richter scale, struck the city of L'Aquila and the surrounding municipalities.

This event shocked the entire territory of L'Aquila, which was unprepared for an earthquake so violent, especially due to the historic nature of many of the towns. Few seconds were enough to paralyze the resident community and its facilities.

The use of temporary systems has been the only solution to meet the changing needs of a territory which since that day has been subjected to continuous development. There are different types of temporariness, according to the performance that are required and conditioned both by the usage time of the temporary structures and by the function they must perform.

1.1 Temporariness in the first emergency

A few hours after the earthquake, temporary systems have been used to quickly restore the functions needed for survival (shelter areas, kitchens, health centers). The operations concerned the immediate emergency accommodation of the population in tents and hotels in neighboring Adriatic coast. In the first 48 hours 27,772 people were rescued (17,772 in camps and 10,000 in hotels) and 30 areas of shelter, 2,962 tents, 10 field kitchens and 13 health centers were set up. In the days following, the rescue operation was continued, reaching up to 67,459 people assisted (35,690 in camps and 31,769 in hotels) and reaching 71 areas of shelter, 5,957 tents, 107 kitchen sets and 47 health centers [1]. Tents have been used to answer the first emergency, according to the model P.I. 88 as prepared by the Italian Civil Protection in the case of hazardous event, because they are portable and easy to store and quickly implemented. The ministerial tent P.I. 88 weighs 233 kg, can be installed by two people in about one hour and it has a footprint of approximately 7.5 x 7.5 meters. The tent's parts are carried in 4 bags, that weigh respectively 95 kg, 69 kg, 65 kg and 4 kg. The tent consists of a pvc platform covered by a carpet, a structure built with steel rods and joints incorporated (single and double junctions with safety catch). The structure is braced with ropes, to which a tent outside, locked to the armor with integrated ribbons, and an inner tent, hanging to the structure with U profiles, are attached. Both tents (outside and inner) are equipped with 4 windows. Inside the tent is divided by a central divider and 4 sides. The tent is fixed to the ground with pegs [2].

1.2 Temporariness in the intermediate phase

After the initial emergency phase, the intermediate phase is replaced, namely the phase that exists between the first rescue and the restoration of the situation prior the tragedy, in which it is necessary to facilitate the reconstruction operations and to protect waiting people. In addition, the high historical value of buildings in the area, combined with the ingrained conception of building in a stable form

has generated the need for medium-long reconstruction. In this phase there are two types of temporariness with different characteristics, but with a similar time of use: temporary housing systems and provisional systems for implementation of safety measures in the existing buildings.

1.2.1 Temporary housing systems

The temporary housing systems have the objective to ensure satisfactory living conditions for the population and, therefore, they must meet specific health standards, privacy and comfort, but also flexibility, adaptability and reversibility that are appropriate to the permanence in the place for some years, although temporary. In L'Aquila's territory the institutions have opted for an extension of permanence in tents, until the construction of prefabricated housing systems, avoiding to build intermediate systems such as containers and trailers, contrary to what is instead in previous earthquakes in Italy (Iripina, Molise, Umbria). This has produced economic benefits and has allowed to invest more capital on prefabricated housing systems, but has increased the discomfort of the population that stayed for a long time in the tents. In fact, the first district of temporary housing units (M.A.P.) was inaugurated in Stiffe (San Demetrio Vestini) in August 21, 2009, namely after 137 days of permanence in the tents. The first Antiseismic Sustainable Eco-Friendly Complex (C.A.S.E.) were opened in Cese di Preturo and in Bazzano in September 29, 2009, namely 176 days after the earthquake.

The housing systems used differ in low and high density districts. Low density Districts (Temporary Housing Units) were built in the municipalities, where the population had grown accustomed to living in single family homes, involving 141 areas, 21 of which are in the town of L'Aquila. Unlike the high density districts (Antiseismic Sustainable Eco-Friendly Complex) were built in the town of L'Aquila, where the population had grown accustomed to living in condos, involving 19 areas [1].

But this typological attention does not match, however, to a similar spatial, constructive and social attention.

1.2.1.1 Temporary housing units (M.A.P.) The modules are divided in: MAP 40 with a surface area of $40 \text{ m} \pm 10\%$ for families of n. 1 person, MAP 50 with a surface area of $50 \text{ square meters} \pm 10\%$ for families of n. 2–3 people and MAP 70 with a surface area of $70 \text{ m} \pm 10\%$ for families of n. 4–6 people. The modules have outside areas that facilitate the customization of the property. The modules have a ground attack, formed by reinforced concrete platforms with a thickness of about 20–25 cm, in which the tubes are inserted to the connections of services (water, electricity, gas and sewer). On the platform, proofed thanks to a bitumen, are dowelled wooden beams for support of the walls. The closures are made up of vertical and horizontal prefabricated wood structural systems or self-supporting frame or platform frame, interposed with thermal insulation. The closures must ensure a transmittance value equal to $0.40 \text{ W/m}^2\text{K}$ for the vertical walls and equal to $0.35 \text{ W/m}^2\text{K}$ for the coverage.

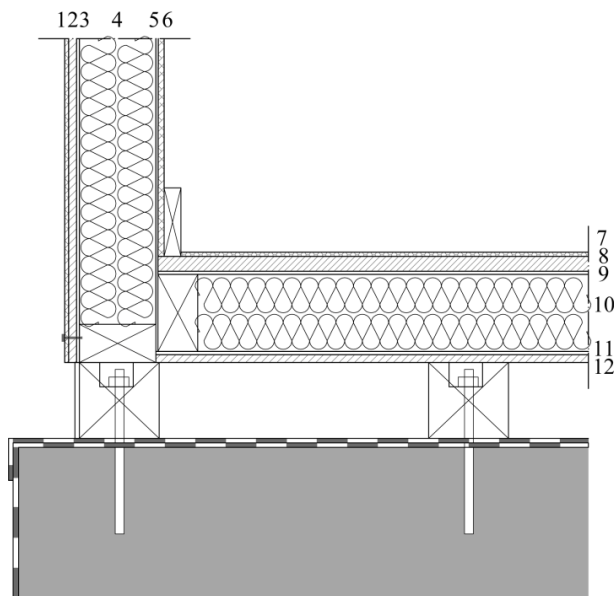


Figure 1: Poggio Picense's M.A.P. – vertical closure: 1 exterior finish, 2 OSB panel, 3 breathable fabric, 4 rock wool, 5 vapor barrier, 6 plasterboard – horizontal closure: 7 linoleum flooring, 8 OSB panel, 9 vapor barrier, 10 rock wool, 11 breathable fabric, 12 OSB panel.

1.2.1.2 Antiseismic sustainable eco-friendly complex (C.A.S.E.) The projects C.A.S. E. have high density building types. All buildings have a footprint of 566 square meters floor plan. The structural part is constituted by two reinforced concrete plates, with thick of 50 cm, separated by pillars of 2.6 meters in height, which support the seismic isolators. Each plate has the dimension of 21 x 57 meters. The building is spread over three floors, arranged on the top plate. Types of accommodation include: apartment of 32 mq, apartment of 54 mq and apartment of 72 mq. From a structural point of view, the buildings are made with prefabricated systems, namely structural panels in plywood (50%), prefabricated panels of reinforced concrete (30%), steel (20%). The casings are made from ventilated walls, concrete elements or wood panels, fiber reinforced, precast walls plastered, and the thermal insulation is obtained by wood fiber, rock wool, cork, polystyrene and polystyrene [3].

1.2.2 Provisional systems to secure existing buildings

In the city of L'Aquila, the reconstruction cannot be performed simultaneously on the whole territory, especially in reference to the historical center, because its conformation underlies a sectors organization, with the aim to avoid the interference of yards and resulting logistical inconvenience.

The reconstruction involves primarily the reactivation of the streets, freeing the streets from the rubble and by securing all dangerous buildings. In the crater still there are ongoing aftershocks, together with the degradation undergone over time that could cause the collapse of damaged buildings. Therefore, the provisional systems are necessary both to preserve the artistic and historical value of the buildings and to ensure the safety of technicians and workers, who work on reconstruction, and the safety of the population which, albeit slowly, is reclaiming the city. The provisional systems are, by definition, temporary works. At the time of reconstruction these systems are removed because isn't longer necessary to carry out their function, being restored to the box-like behavior of the housing. They have been used mainly dry systems that have enabled rapid assembly, responding to the emergency situation, in which they were placed in work, and that will allow rapid disassembly, thus speeding up the reconstruction. The temporary works to secure existing building can be classified according to their function.

The shoring have a replacement, precautionary or protective function, they create a structure that ensures the functioning of the shoring with the damaged structure in solidarity. They can be shoring retention, shoring contrast and shoring support. The shoring retention reduce the buckling length of the walls, counteracting the bulging phenomena of the wall towards the outside or the tilting out of the plane. They have a shape oblique that puts in contrast the damaged item and the element placed in work. The shoring contrast prevent tilting phenomena or bulging phenomena of the walls of adjacent buildings. They have a shape contrast between the two buildings with elements of vertical distribution, adapted to avoid hammering in case of earthquake. The shoring support contrast the vertical displacement of the horizontal elements (floors, beams, etc.), support parallel vertical elements (walls, columns, etc.) and prevent the fall of the wall borne by an opening. The shoring are arranged in vertical and pressure loads.

The hoops have a containment function and serve to counteract the compression and/or shear efforts, thus avoiding bulging or swelling. They are particularly effective for compact elements (towers, columns, bell, etc.). The hoops can be placed around the entire perimeter or on a part of the perimeter anchored laterally.

The tie-rods serve to guarantee the behavior of the box-shaped building, counteracting the tilting of the walls, due to the lack of clamping or to the presence of other horizontal pushing. There is applied to a containment action localized, thanks to rods brought to traction, which is distributed with uprights and stringers. The tie-rod can be arranged on opposite walls or on a single wall, through the passage of the tie rods parallel to the transverse walls or inside the building.

The jacketing prevents the bulging of the wallboard, caused by excessive vertical loads. The wall is pierced, stiles and rails are positioned to distribute the loads and tensioned steel bars with plates of contrast are placed.

The coverages (often independent of the building) protect the buildings that have suffered the collapse of the original hedge, against weathering.





Figure 2: Provisional systems to secure existing buildings in L'Aquila.

To carry out provisional system to secure existing buildings, construction systems in wood and/or steel have been used. Specifically there are tubular scaffoldings, that consist of steel pipes of an external diameter of 48.30 mm, thickness 3.20 mm and lengths ranging from 500 mm to 6,000 mm, connected by orthogonal joints (that only allow connection to 90°) or swivel joints (which allow bi-directional rotation of 180°), tensile joints (which allow the connection between two pipes under tensile); the joints are equipped with a central core and two bolts with nuts and washers that allow tightening. This system has high reversibility and high flexibility, because, separating the joint from the pipe, it is possible to cut the pipe according to the size needed, without compromising the possibility of connection and it is possible to vary the height positioning of the joints along the pipe. This allows their use in any situation (in the presence of arches and vaults or in the case of a conformation planimetric very articulated).

There are multidirectional systems that consist of steel pipes of an external diameter of 48.30 mm, thickness 3.20 mm and the default variable length from 250 mm to 4000 mm, with incorporated joints. The attack between vertical and horizontal pipes is via a rosette incorporated with 8 holes in vertical pipes and attack with a clamping wedge in the horizontal pipes, while the attack between vertical tubes in high takes place via an interlocking system for threading. The system has high reversibility, but the presence of joints incorporated with the tubes, if, on the one hand speeds the time of assembly and disassembly, on the other hand makes the system inflexible, as it is not possible to cut the tubes in function of needs or make any second angles other than 90°.

There are steel structures, that are made up by roofing systems or modular towers, which use various types of steel profiles and steel elements united with reversible connections (predominantly bolting) and they can be separated from the building or integrated with it.

There are metal profiles and steel cables, have been used primarily coupled UPN profiles 120, 140, 160, 180. This profile was chosen both for its conformation, that allows for easy anchoring of mounting plates and of plates of contrast, and for the high amount of material needed, that had to relate to the availability of steel components at the time of installation of provisional systems.

The metal profiles are arranged in grids of mullions and transoms, placed in adherence to the building through steel cables, connected with turnbuckles and plates of contrast. The system has high reversibility when the profiles are joined by means of bolted plates, average reversibility when the profiles are welded in place, because before being transported, the profiles must be cut, with an increase of time and costs for dismantling. The steel cables are always tensioned, thanks to systems with nuts and screws that allow easy disassembly. The system is not flexible for its conformation (as is the case of the tubular scaffoldings), but the careful design ensures its reuse in many areas.

There are polyester clamps, that are 5 cm high and they are tesate by ratchets with manual adjustment, providing angular beveled wood in the corners at 90°, for avoiding abrasion of the polyester. They have a high reversibility and fast assembly, but can only be used in cases of very compact hoops items such as columns or portions of the building.

There are also many wood systems. Morals are used for shoring of arcs or vaults or for reinforcement of the openings, beams for retention and contrast shoring and boards for distribution of loads on vertical and horizontal planes. Wood has a high reversibility, because connections are made for riveting, clamping, bolting and for adhesion. It also can be cut with ease according to requirements, but has the limitation of being subject to quickly degradation and it is difficult to reuse, when it is removed.

These provisional systems are often integrated each other, depending on the requirements that they must meet.

2 Problems

The need to quickly overcome the state of emergency generated by the earthquake coupled with the need of acting on a large scale, namely on the whole territory of L'Aquila, stimulated functional solutions exclusively aimed to the time being contingent and is not intended to future developments in the area. A lack of planning that is expressed in the emergence of new problems related to the interventions that have been made to solve the problems of the post-earthquake, without any foresight.

2.1 Tents, M.A.P. and C.A.S.E. projects: is temporariness real?

The temporariness consists of three declensions: the temporary nature of construction, namely the ability to trace back the path, that led to the definition of the building organism, the temporary use, namely the ability to transform the space according to different configurations and the temporariness of localization, namely the transferability that allows to vary the relationship between the environment and the construction [4]. In function of these declensions, housing systems used in L'Aquila were analyzed, to evaluate the effective traceability to the temporariness. In the first emergency it was put in place the tent that due to its intrinsic characteristics is a symbol of temporariness. In fact, the tent allows temporary use, thanks to the flexibility in shaping the interior space, the

temporary location, the adaptability to environmental conditions and the ease of transportation, and the temporary nature of construction, due to the high reversibility of all connections and the attack on the ground.

Unlike we cannot define as temporary the housing systems used in the intermediate phase, though born with this intent. The M.A.P. and the C.A.S.E. projects do not have reversibility features, such as to ensure the temporary construction. While in one hand the reversibility of the system is ensured by the high degree of prefabrication and by the use of dry technologies for the structure of vertical and horizontal closures, on the other the reversibility is negated by the use of glued connections and moist external finishes (for example plaster) that, when they are removed, don't allow the integrity of the components, for the purpose of a future reuse. Furthermore, the ground attack is in reinforced concrete and it can't be definitely defined reversible. The low reversibility of the system has produced a high consumption of land, making such interventions unsustainable. The reversible ground attack is one of the conditions of temporary architecture, as it strongly influences the possibility of moving the architectural organism, namely the temporary location. Failure to self-sufficiency of the installations has necessitated works of primary infrastructure that are very incisive in the area. These systems cannot be disassembled and transported elsewhere with ease. In addition to that, their rigid conformation space, that configures the default sizes of accommodation, doesn't allow the transformation of space, as a function of a change in intended use and as a function of user needs. The M.A.P. and the CASE project, although born with the intent of temporariness, because there are intended for the people who at the time of reconstruction abandon these accommodation, can't be considered temporary systems because they don't identify with the characteristics of the declensions of temporariness. Moreover, there is a discrepancy in the durability of the components used, that are put in place to respond to a need temporary, but that will have to be subjected to numerous maintenance to ensure their reliability for a longer time than originally planned.

2.2 The end-life of provisional systems to secure existing building: lack of programming

The provisional systems to secure existing buildings were provided and placed in work by the Fire Department (mainly wood systems) and for a small part and the remainder by private companies, through competitions organized by the municipalities. Only in the town of L'Aquila were spent approximately €188 million, according to official data [5]. Starting from the unit price and from a qualitative percentage assessment of these systems, it is possible to estimate the amount of material placed in work in L'Aquila. In the town of L'Aquila have been used approximately 40,000 cubic meters of wood, approximately 400,000 ml of polyester clamps, about 10,000,000 kg of steel, about 2,000,000 elements of tubular scaffolding or of multidirectional systems. At a time when the operations of reconstruction of a building start, the systems of temporary safety measures must be gradually dismantled. The dismantling and the subsequent disposal are a significant economic cost for the municipality of

L'Aquila, owner of such systems. Taking as reference the steel, namely the material that have the greatest value at the end of life, between those used, the gain that comes from its resale as used steel is lower than the cost of dismantling and transport to landfill. Even if we neglect the economic cost and the numerous logistical hardships, due to the disposal of a large amount of material in a few years, certainly we can't overlook the environmental impact that results from failure to reuse. Currently in most cases, the materials that constitute the provisional systems are transported to the landfill. Sometimes they are repurchased by the company at favorable prices, but there aren't precise criteria for evaluation of the purchase price, which is estimated from time to time. These materials represent a waste in the current situation, that doesn't have a precise location.

The programming of the end of life scenarios is required in the interests of environmental sustainability of the whole process, with the aim of exploiting the embodied energy still present in the materials.

3 Possible future scenarios

Currently, in reference to M.A.P. and C.A.S.E. projects it is difficult to predict future scenarios of use, due to the uncertainty of the time of use in accordance with the current destination, namely the time of reconstruction of the city of L'Aquila and neighboring centers. The actual stability of these settlements creates a problem unsolved, on which planners, architects, technologists are questioning, looking for a new model for the city, that is able to integrate the "temporary quarters" in a renewed territorial organization, and looking for new uses to ensure satisfactory performance ("widespread hotel", students homes, home-office) to users.

Otherwise in relation to the planning of future scenarios of the materials that make up the provisional systems, the reconstruction, currently in act, imposes a methodological approach that defines operational guidelines to ensure the sustainability of the process.

3.1 From waste material to resource: re-temporariness

Through the programming of possible reuse/recovery interventions, the huge amount of steel and wood used for provisional systems could become a resource readily available, because it combines the use of Km 0 materials with the reuse of waste material. The use of local materials produces numerous environmental benefits, including the reducing of the environmental impact of transport. At the same time, the reuse of waste materials reduces landfill, minimizing the environmental impact of production *ex novo* and the disposal of material.

The reuse and recovery of materials, that are part of provisional systems, might produce economic benefits for municipalities, which since they are owners of the materials with a market value; they could make a profit from the sale, obtaining the relief of the burden of dismantling and of disposal. In addition, the reuse and the recovery of the materials, that are part of provisional systems,



might produce economic benefits for companies that could buy materials at favorable prices. The purchase of materials immediately reusable inside the reconstruction yard by the company reduces the time needed for the procurement and eliminates the problem of storage within the yard, with obvious logistical advantages for the yard's organization.

The methodological approach proposed is designed to encourage the purchase of the material, that constitutes the provisional systems by the company, through the establishment of operational guidelines for reuse, within the construction site (endogenous reuse) or for the reuse outside the reconstruction site (exogenous reuse). The endogenous reuse and the exogenous reuse envisage a change of function in the temporariness, a re-temporariness. The temporary nature of the provisional systems, aimed to the preservation of the buildings and the population, becomes the temporary nature of construction systems to carry out works to simplify the organization of the reconstruction site and to restructure public spaces, according to a cyclical process that doesn't produce waste, but only a controlled evolution in respect of environmental sustainability.

3.1.1 Endogenous reuse

The endogenous reuse occurs within the site of reconstruction. The company, which was awarded the contract for reconstruction, disassembles provisional systems and divides materials for a residual performance. A portion of materials can't be reused due to constructional features and/or degradation and this portion is first stored and then transported to incinerators, for recovering of feedstock energy, or in landfill. However, a portion may be immediately reused in the reconstruction site. While the disposal is only a burden for the company, the reuse is an advantage. Therefore, the convenience to purchase by the company depends on the ratio between the part that can be reused and the part that, instead, must be discarded. In this sense, the wood systems and the polyester clamps are difficult to reuse. The convenience is also evaluated according to the type of available provisional systems and in function of their flexibility of use.

In fact, according to the type of systems used and the components that constitute them is possible to put the components in the reconstruction project or to build temporary works construction. In the case of insertion of components in the reconstruction project, aimed to repairing or reinforcing, systems with metal and steel cables are more suitable. For example it is possible to reuse steel profiles for consolidation of the floors, of the beams, of the columns, of the window's or door's lintels and for stiffening the front. It is possible to reuse corrugated sheet metal in the coverage or in the floor or it is possible to reuse steel cables for vertical suspended connectives, etc. In the case of reuse of materials for temporary service structures in yard, tubular scaffoldings and multidirectional systems are more suited, because they have a greater flexibility, short assembly times and high reversibility. The construction of temporary service structures in yard are made by both systems scaffolding needed to carry out the work, and by construction equipment such as the canteen, changing rooms, offices, storage areas covered. In this regard, with reference to the historical center of L'Aquila, the simultaneous reconstruction of several

buildings requires the accommodation of construction equipment in a common area, reusing materials from the provisional systems of all buildings, with the order to limit interference between the various sites and, at the same time, to have a greater availability of material to reuse. In the event that the systems have been used to build temporary construction equipment, at the time of completion of the work, the company can disassemble these systems and can store them in stock until further use, if needed, or it may sell material to another company that will reuse them outside the site of reconstruction. In both cases the company has the advantage of having a low-cost readily available material.

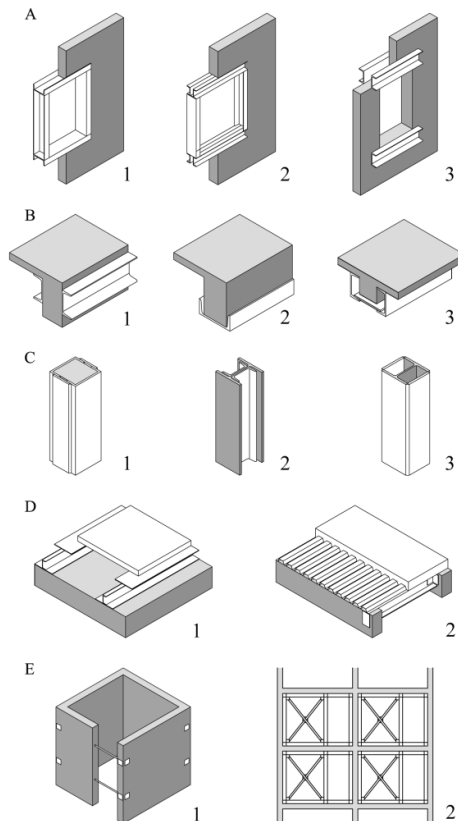


Figure 3: Hypothesis of endogenous reuse with insertion of steel components in the reconstruction project – A1 opening consolidation, A2 opening consolidation with profiles coupled, A3 lintel external reinforcement – B1 beam consolidation laterally, B2, B3 beam consolidation with support from under – C1 pillar reinforcement, C2 increment inertia on two axes, C3 increment inertia on the minor axis – D1 restore plant-interspace, D2 floor structural reinforcement – E1 restoration of building box-like behavior, E2 facade stiffening by cross bracing.

3.1.2 Exogenous reuse

The exogenous reuse occurs outside the yard of reconstruction. If the firm, which is working to reconstruction, hasn't interest to buy the material of provisional systems by the municipalities or, once the reconstruction is completed, hasn't interest to preserve the property of materials and to store them in the warehouse, the material may be resold/transferred to another company. The exogenous reuse can take place through the construction of temporary structures for regeneration of interior and exterior spaces, thanks to the identification of building systems that reuse provisional systems, as tubular scaffolding, profiles and multidirectional systems or their components, integrating them with local resources. Integration with other Km 0 materials also allows to reactivate the economy and promote the development of this area that, after suffering a catastrophic event, is often mortified. They are temporary building systems that retain features of reversibility and flexibility of the systems that have originated them. In view of the environmental sustainability of the building organism, in the international scene, numerous experimental projects are implemented, involving the reuse of both, waste materials and local materials. In none of these experiments, however, there is such a large amount of "local waste" material as in the city of L'Aquila. This allows to test numerous building systems according to the requirements which must be satisfied, and to experiment the use of the same component with different functions. For example, a UPN beam can play both the structural function and the function of cant line for the plant interspace.

4 Conclusions

Starting from the study of the reality of L'Aquila it is possible to define a methodology to answer the lack of planning and multiple needs of an area that, in its process of rebirth, undergoes rapid changes, through the temporary. The possible change of function from the provisional system to building system, shows that the temporariness, when it is real, requires a continuous renewal of the system and a renewed cyclical (re-temporariness). The temporariness, unlike stability, when it is being put in place, doesn't care about the real future scenarios, but it is only the assumption that these scenarios could actually exist in the future, regardless of the conditions existing in the environment.

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