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Wooden framed structures for masonry buildings retrofitting. A pilot project in Caporciano

Drewniane konstrukcje ramowe w naprawach budynków murowanych. Pilotażowy projekt w Caporciano

Keywords: Masonry retrofitting, Reuse, Mix Structural System, Wooden structures

Słowa kluczowe: uzupełnienie konstrukcji murowanych, ponowne użycie, mieszany system konstrukcyjny, konstrukcje drewniane

1. INTRODUCTION

The study refers to the masonry buildings ruins rehabilitation in the post earthquake of Caporciano (L'Aquila, Italy). The philosophy at the bottom of the reconstruction plan wants to rehabilitate the buildings, in case their integrity is acceptable.

In case the existing buildings are ruins with an evident evocative character, we think it is desirable to strengthen them by a partial transformation – with contemporary technologies – with the purpose of re-establishing their use.

Fig. 1. The state of conservation of the existing masonry buildings

For the existing building rehabilitation we propose wooden systems. The proposal comes from the aim of keeping and conserving the heritage, but without making historic fakes reconstructions. This is a way for integrating the "memory" with the new buildings in a harmonic relation and testifying the necessary evolution for satisfying the current life an environment needs.

For bestowing new use possibilities on ruins, we do not propose an existing buildings reconstruction but a construction in the existing buildings.

This construction assumes also the role of defence against new seismic stresses.

The plan proposes a construction on the existing building. The intervention choices admit the opportunity of "repairing the damages", "leaving things almost unchanged", that is to say using sustainable constructive materials and systems, that are compatible with the existing buildings characteristics even if different and "transfer".

2. THE RUINS REHABILITATION THROUGH WOODEN SYSTEM INTEGRATION

The building systems rehabilitation, we designed, foresees the integration of light and removable systems in the conservation of the masonry systems "ruins". The wooden systems have the double role of making the buildings re-usable as well as to lend them security.

We propose the "insertion" of self-bearing volumes in the existing masonry walls, that are able to consolidate and stabilizing the existing structures (through horizontal wooden and iron system). The new volumes have wooden and iron bearing framework and wooden and glass closures.

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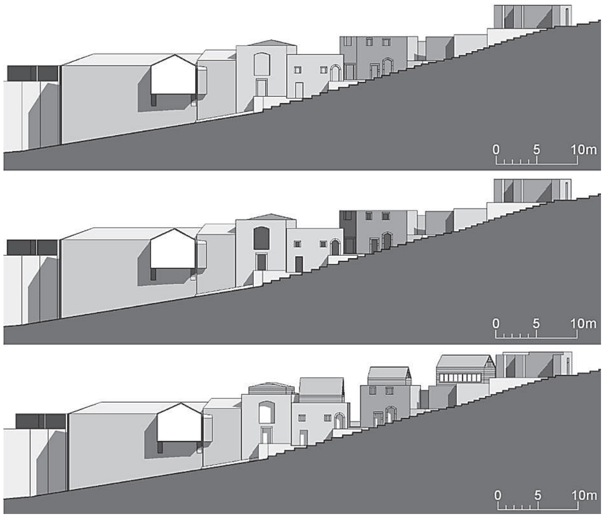

Fig. 2. Front view of the existing buildings, the removed parts (in red) and the insertion of the new wooden buildings

These new volumes can exploit as much as possible the climatic factors (wind and sun) for internal spaces natural ventilation, illumination and acclimatization.

So the new volumes can supply the lost performance levels, above all for what concerns the safety, well-being, usability, management and aspect. In this direction, we reassert the importance of satisfying the intervention reversibility needs (together with those of sustainability and safeguard). The reversibility was recognised as a fundamental character of the human activities (such as to make architecture) of our age.

Planning and building according to the reversibility paradigm means to admit the inversion possibilities of the constructive process: from the realization to the "zero remains" disposal.

The reversibility of the constructive sequences in the building processes, indeed, means above all the possibility of recovering constructive materials and elements as well as of repairing almost totally the intervention ex-ante conditions. So reversibility means not transforming in an irreparable way the existing masonry systems.

The considered settlement of the intervention lies in Caporciano, in a midway position between the old town hill and the plain expansion area. The settlement consists in some masonry walls part of an original multi-storey (2 or 3) system; the current condition of this system, now show ruined attics and roofs as well as missing casings.

We chose to strengthen the existing walls and to settle (inside the perimeter given by the old walls) a new wooden framed and wood fibre insulated building. The roofs, conveniently oriented, will be able to produce renewable energies (thermal solar and photovoltaic systems) and the plants will lean to minimize the water consumption, recovering rainwater and recycling grey waters, as well as to hold back the other consumption.

In synthesis the proposal comes from the following objectives:

- the answer to the function specific needs linked to new and traditional family units,
- the environmental sustainability general needs,
- the choice (fundamental for the sustainability objectives) of rehabilitating the existing buildings.

3. THE ENVIRONMENTAL SUSTAINABILITY NEEDS AND THE WORKS REQUIREMENTS AND PERFORMANCE

We faced the emissions, the waste production and the resources consumption curb, considering the building materials, the water and the energy.

The choice of working on the existing buildings with a rehabilitation and renovations project guarantees the soil consumption curb. So the existing buildings rehabilitation and strengthen costs are balanced out by the saving due to the avoided ruins demolition and debris storage works (that involve also environmental impact and transport to dump costs).

The polluting emission curb is given by the reduction of the CO_2 production. The proposed constructions are Class A certified thanks to the use of more efficient plants, against the traditional ones and the use of renewable energies and certified materials.

For the reduction of waste production we considered principally the building and demolition waste which are one of the most polluting source. SO we decided to rehabilitate the ruins that otherwise would have become, if demolished, a big quantity of debris causing a big environmental impact and dump problems.

For what concerns the building materials, we considered natural and renewable resources with low energy worked in. According to the zero Kilometres philosophy, for the vertical and horizontal closures, we chosen technological systems made by industries situated as closer as possible against the yard.

For what concerns the drinkable water saving we foresee rainwater collecting plant and a grey water management system. The rainwater recovery and the grey water management allow to minimize the drinkable water consumption and to have a quantity of water, which can be used outdoor (as for irrigation).

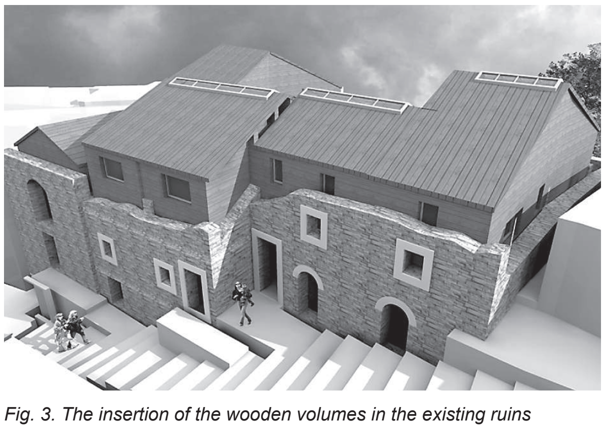

Fig. 3. The insertion of the wooden volumes in the existing ruins

For what concerns the energy saving we used, as renewable energetic sources, solar panels (26 square metres of vacuum packed panels) for the sanitary warm water and for the heating, and photovoltaic panels (50 square metres), for the electricity production.

The thermal solar plant concurs for the 70% to satisfy the sanitary warm water and the heating need. The remaining 30% energy need is satisfied by pellets (in the future supposition of a local production from the woody and farm system management) or methane gas hot-water heating. The photovoltaic plant satisfies over the 50% domestic electric energy need.

For satisfying the usability needs, the existing building dimensions allows to organize six accommodations for twelve persons (with the annexed services), suitable for guaranteeing the spaces comfort and quality. The access to the area and the ways are adequate to be covered by baby carriage and disabled wheelchair.

For satisfying the well-being needs, thermal comfort and the natural illumination are the most considered elements in the project. We considered the climatic resources for complementing the heat intake, favouring the ventilation and implementing the natural illumination thanks to bio-climatic device.

Fig. 4 The masonry buildings before and after the rehabilitation works

The plants were conceived to define a system integrating renewable energetic and traditional heating plants. For better optimizing the heating production and management, we propose the installation of a centralized plant using a floor radiant system so to improve considerably the energetic efficiency of the building-plant system.

For satisfying the management needs, the chosen dry-stone systems facilitate ordinary maintenance works and, in particular, allow configuring sustainable life end strategies (reuse, rehabilitation and components recycling).

Other important requirements defined with the design are the spaces adaptability and flexibility. The facility of displacement of the partition walls allows obtaining different accommodation typologies.

Also the plants are flexible that is to say that the possible elimination or different positioning of some toilet facility do not requires destructive works but just dismantling works.

For what concerns the satisfaction of the integration needs, the choice of rehabilitating the ruins comes from the will of conserving the patrimony without making reconstruction of historical fakes.

Therefore the project consists in the integration of the "historical memory" with the new building in a harmonic relation and showing the necessary evolution for satisfying the current life and environmental needs.

For what concerns the satisfaction of the environmental safeguard needs, we selected the building materials searching the as smaller as possible impact.

Anyway the objective is to implement the local conditions proposing the use of local products and the technological systems simplification above all in the use of materials with supply short weaving factory.

For what concerns the satisfaction of the aspect needs, after the works the ruins acquire a complete image.

We suggest realizing systems able to restore the morphologic and dimensional integrity of the existing buildings. So we transform the collapse perception reality in memory.

The distinction between the ruins and the new constructions is immediately thanks to the strong difference between the original and the new materials and constructive systems. On the other hand the overall image results uniform because we do not alter the local buildings volumes traditional shapes and dimensions.

4. THE MASONRY RUINS STRUCTURAL RETROFITTING

4.1. Introduction

As regards the safety demand, the structural typology chosen for the residential buildings and the social service buildings is a mixed system: the old survived masonry ruins (opportunely refurbished and consolidated) connected and collaborating with new wooden 3D box-framed structures.

The old and damaged masonry structures are consolidated through local reparations, local little demolitions and reconstructions, mortar injections and a layer (40-50 cm of vertical thickness) of reinforced new masonry (reinforced by means of steel or PVC nets placed inside the horizontal mortar joints) on the free top of the masonry walls. The complementary wooden structure, connected to the masonry, guarantees structural box behaviour in case of seismic actions. As it is well known, for the seismic behaviour of masonry buildings, it is necessary to guarantee that the structure works as a closed box, in such e way to redistribute the horizontal loads among all the vertical masonry panels, without to leave some of these panels working alone and overloaded along its own weaker principal axis.

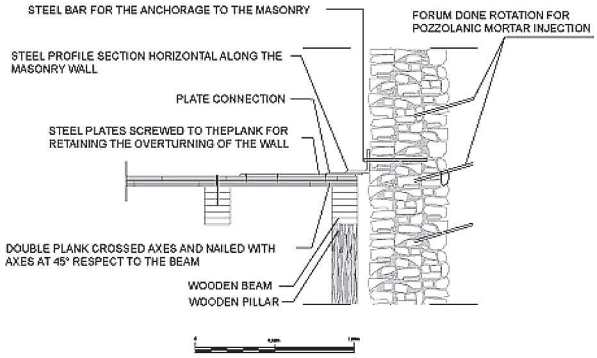

Fig. 5. The link between a masonry wall and the wooden frame at a floor level

What is more, to develop a box behaviour means that the floors stiffening, in their horizontal own plane, avoiding relative deformations of the horizontal plans at the upper levels, improves the structural collaboration among the walls in such a way to improve the global torsion resistance; this structural need arise as torsion effects are always present (especially in existing buildings non specifically designed taking into account the seismic actions) because of the not regular masses distribution in relation to the global horizontal shear stiffness centre.

4.2. The pilot project

In this pilot project the closed box behaviour is obtained through trussed elements in all the horizontal panels of each level, in the roof level, inside the vertical wooden frames and by the connection among those horizontal and vertical wooden panels and frames.

The trussed elements are made by steel ties or by wood; in the case of the wooden floors the horizontal shear stiffness

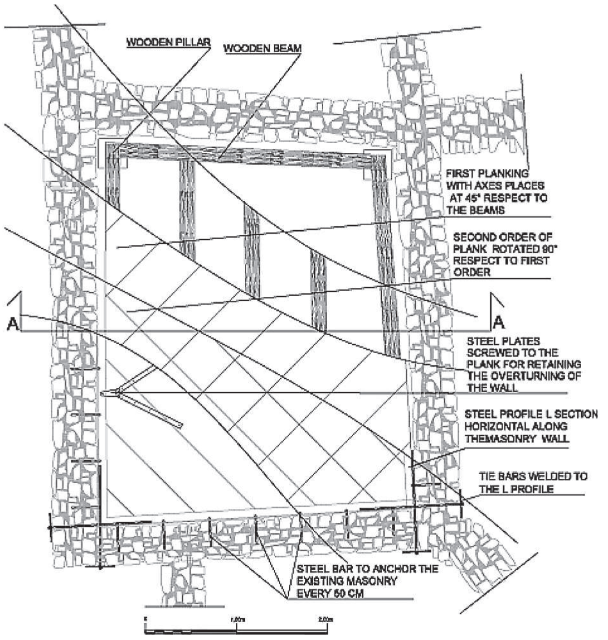

Fig. 6 .A typical floor plan view with the double layer of crossed planks and the connections between frames and masonry

is provided by the over position of two or three horizontal layers of planking placed in cross directions, fastened each to the other and connected to the vertical frames as reported in Figures 5 and 6. The wooden 3D trussed frame is connected to the masonry walls by means of steel plates (or bars) fixed to the masonry using steel stirrups.

A similar connection to the masonry is provided at the roof level also, in those cases where the survived walls are standing up with their total original height as reported in Figure 7. At the roof level it is the roof itself that provides the horizontal shear stiffness, thanks to a double layer of crossed wooden planking.

In addition to the retrofitting for the bending actions orthogonal to their own main plane, the masonry walls are reinforced also for shear actions parallel to their own plane, using trussed vertical wooden frames placed parallel and near to each masonry wall.

These vertical shear resistant elements are built by wooden frames trussed by diagonal steel bars.

The vertical trusses collaborate with the masonry walls up to the top of the ruins and work alone in the upper part of the new wooden structure, at the levels where the masonry is no more present.

As regard the shear actions parallel to the principal plan of each wall, the collaboration between the new wooden structure and the masonry walls is mainly significant during the non linear behaviour before the ultimate load of collapse: this because of the high shear stiffness of the not damaged masonry walls limits the new structure work, in case of not very strong horizontal actions.

On the contrary, as regard the bending and overturning actions orthogonal to each masonry wall main plane, the collaboration between the two structural systems arise earlier, with lower values of horizontal actions, because of the lower ultimate load of a masonry wall subjected to transversal overturning actions, respect to the case of shear actions parallel to the wall itself.

Thus masonry walls are maintained in their vertical positions by the trussed wooden frames and the links between these two structures are placed at each horizontal level.

Each horizontal shear stiffened floor is completed by means of steel "L" or "T" profiles fixed (screwed) to the double planking, all along the perimeter of each floor (Figures 6 and 7), like horizontal frames. These steel profiles are then also connected to the masonry every 50 cm all along their length.

These steel frames works also as horizontal chains, connecting the masonry walls along the principal directions of each building.

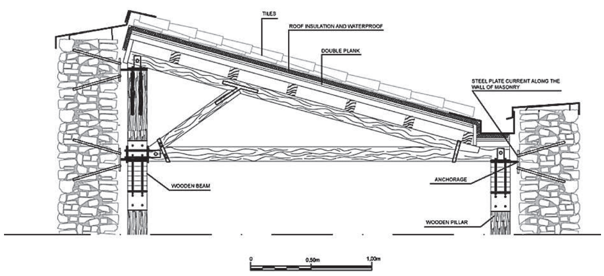

Fig. 7. An example of roof structure with the connection to the masonry, in a case where the masonry walls have their original elevation

For this purpose and also for the purpose to obtain a strong connection of the floors with the masonry corners, the steel profiles are welded to steel tie bars passing through the masonry at each floor corner, as reported in Figure 6.

The new wooden frames have a foundational structure which works also as an improvement and an enlargement of the original masonry walls foundation.

In Figure 8a it is reported the first phase of the building up of the new structure, with the consolidation of the existing foundational structure and the digging of the space for the new foundation. In Figure 8b it is reported the new structure with the foundation linked and integrated with the original one.

As regard the original masonry structures, the parts not very damaged are consolidated with pozzolanic mortar injections, while the more damaged are repaired with partial dismantling and rebuilding with the technique of the "reinforced" masonry.

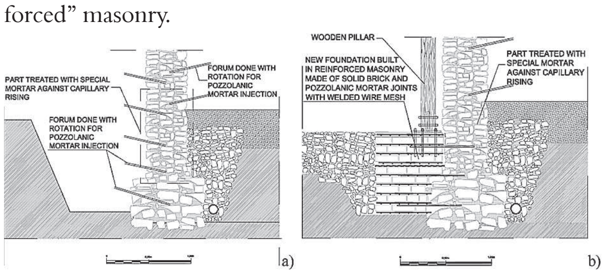

Fig. 8. The restoration of the masonry foundation (a) and the new wooden frame foundation (b)

That technique, in the case of restoration of existing masonry structures, consists in the use of the original stone blocks (or blocks recovered from the collapsed portions of the structure), in the use of pozzolanic fibre-reinforced mortar and in the placing a thin steel net (made by wires with no more than 2 mm of diameter) or a PVC net (fibreglass reinforced) inside some of the horizontal mortar joints. Generally the reinforcing net has to be placed every two or three horizontal joints along the vertical direction.

This is the same technique used for the reinforcement of the top of the masonry structure partially collapsed, with the aim to structurally "close" (and to protect to the weathering) the free top boundary of the wall. However the same technique is used also on the top of those walls still standing with their original height, in such a way to reinforce the link with the roof structure.

The new wooden structures, together with all their steel elements and details, are designed and verified in such a way to resist without serious damages to the design seismic action provided by the Italian Code for the pilot project site, which is inside the Caporciano Municipality area, where they have to be considered horizontal seismic ground accelerations in the order of $a_g = 0, 265$ g.

5. CONCLUSIONS

The proposed projects wish to suggest an interventions realisation aiming to guarantee a local sustainable development also through the choice of appropriate building materials and systems.

For this reason, we want to ward off either abandonment phenomena or existing buildings inaccurate transformation works, considering the contemporaneous life styles interests. That is to say, we define the possibility of revitalising the considered place, settling new activities linked to ancient traditions, safeguarding the environment identifying characters. So we want to avoid the risk of transforming the buildings (the ruins) in the "themselves museum". Our proposal represents an application example of how the technology can put into communication ancient and contemporaneous elements (above all for what concerns building techniques and materials and functions).

The developed work tries to interpret and make concrete the "new conservation science" principles in the satisfaction of the current sustainability needs, so that the safeguard and transformation interests find common objectives.

The strengthening of the ruins is integrated in the realization of new wooden systems then the masonry traditional architecture uses the technological innovation of the wooden system for being used again. So we fade the limits outlines between the existing building and the new building design.

REFERENCES

[1] Bologna R., (a cura di): La reversibilità del costruire. L'abitazione transitoria in una prospettiva sostenibile. Maggioli Editore Rimini, 2001.

[2] Caterina G., (a cura di): Per una cultura manutentiva. Percorsi didattici ed esperienze applicative di recupero edilizio e urbano. Liguori Editore Napoli, 2005.

[3] Davoli p. M.: Costruire con il legno. Hoepli editore, 2001.

[4] Forlani C. (a cura di): L'Università per il terremoto. Castelnuovo e l'altopiano di Navelli. Alinea Editrice, Firenze, 2009.

[5] Gasparoli P, Talamo C.: Manutenzione e recupero. Criteri, metodi e strategie per l'intervento sul costruito. Alinea Editrice Firenze, 2006.

[6] Tucci F.: Involucro ben temperato. Alinea Editrice Firenze, 2006.

Abstract

The paper deals with the use of wooden framed structures for the retrofitting and rebuilding of partially destroyed masonry buildings. When the damages are not so large to require a complete demolition but they are also not so localized to permit simple reparations, there is always the problem: how much to rebuild without to obtain an historic fake?

The philosophy at the base of the Rehabilitation Plan for Caporciano (a municipality in the L'Aquila earthquake area) follows two different ways: a) the demolition, when the ruins envelop is less than the 30% of the original building volume and/or the masonry is too much damaged to be consolidated; b) the consolidation of the masonry and their stabilization through the collaboration with new wooden structures built inside the free spaces leaved by the collapsed roofs and floors.

The choice to recover, in such a way, the survived existing structures, descend from the aim to conserve the historical heritage without rebuilding historic fake but integrating the "memory" with the "new" in an harmonic collaboration, testimonial of the necessary technological evolution for the life and environment contemporary needs satisfaction.

The project deals with a new structure inside the ruined walls with two goals: the consolidation and the stabilization of the survived walls and the building of new and efficient wooden volumes, with wooden fibres thermal insulation, inside the perimeters of the masonry walls.

Streszczenie

Artykuł omawia wykorzystanie drewnianych konstrukcji ramowych w naprawach i odbudowie częściowo zniszczonych budynków murowanych. Jeśli uszkodzenia nie są aż tak poważne, aby wymagały całkowitej rozbiórki obiektu, ale też nie tak nieistotne by wystarczyły zwykłe naprawy, zawsze powstaje problem: ile należy odbudować by uniknąć historycznych zafałszowań?

Filozofia leżąca u podstaw Planu Odnowienia Caporciano (miasta w rejonie L'Aquila nawiedzonym przez trzęsienie ziemi) pozwala na dwa różne rozwiązania: a) wyburzenie, gdy zniszczone jest mniej niż 30% oryginalnej substancji i/lub mury są zbyt zniszczone b) konsolidację elementów murowanych i ich stabilizację poprzez wprowadzenie nowych elementów konstrukcyjnych z drewna, wzniesionych wewnątrz wolnych przestrzeni pozostawionych przez zniszczone sklepienia i podłogi.

Decyzja by w ten sposób odrestaurować to, co przetrwało, ma na celu zachowanie historycznego dziedzictwa bez fałszowania zabytku, ale dzięki harmonijnemu zintegrowaniu "starego" z "nowym", co jest świadectwem nieuniknionej ewolucji technologicznej koniecznej by zaspokoić współczesne potrzeby życia i środowiska.

Projekt wprowadza nową konstrukcję do wnętrza zniszczonego budynku z dwóch powodów: w celu skonsolidowania i ustabilizowania ocalałych ścian, oraz stworzenia nowej, skutecznej przegrody drewnianej wypełnionej izolacją termiczną z wełny drzewnej, wewnątrz oryginalnych kamiennych murów.