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Synergetic action of new and existing structures in re-using a 18th century monastery

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ABSTRACT: The project concerns the restoration of a ruined conventual building of the 18th century in Southern Italy, aimed at the insertion of a school complex. A new project was carried out providing for the building of new steel and wooden light structures inserted within the fields defined by the in-plan alignments of the existing walls. The steel structure foundations allow for a minimum interference with the expected underground finding of graves and burials. The masonry walls will be strengthened by mortar injection and tied by the insertion of twin steel beams at the floor levels, joined across the wall thickness by means of passing-through injected bars. A particular solution has been conceived based on the synergetic interaction between new and existing structure. Special connection systems between new structures and old masonry walls allow for a triple function: avoiding the interaction in the vertical load bearing capacity, avoiding collapse mechanism orthogonal to the wall plane through the horizontal bracing effect of the steel frame, using the horizontal load bearing capacity of the retrofitted and strengthened walls in their plane. The adopted structural and constructive solutions are presented. The restoration works are being currently carried out.

1 INTRODUCTION

This paper is aimed at illustrating a project concerning the restoration for the reuse of a three hundred years old ruined monastery, located in a seismic prone area of the Southern Italy.

When facing a ruined building, both the ruin derives from a prolonged lack in maintenance, as in the present case, or from other accidental factors, like earthquakes or fires, three alternatives are present for its recovering.

The basic one consists of the romantic solution of leaving the time takes its course. The effects are only mitigated by means of minimum preservation works or protective external defences. The ruin is considered in its archaeological worth, as witness of historical significance, without architectural utility.

The first of the two operational alternatives consists of the restoration of the ruin by the reconstitution of a copy of the original building. The result is pursued by means of the substitution of the decayed elements and the volumetric, structural, architectural and decorative integration of the lost portions: the lost fragments are rebuilt on the model of the original ones, as resulting from the existing documentation and the survey of the saved elements. In this case the restoration of the building is approved by an accurate historical research, aiming at recovering the original building researching a continuity with the past and, paradoxical, also erasing the signs of the time not contemporary to the original "facies".

The second design alternative concerns the restoration of the ruins through the research of the contrast with the original building. In this case the existing fragments are re-connected by means of new elements resulting complementary but physically and visually separated, thanks to a differentiation of the material and shape. The restoration is carried out through the building of elements independent from the original ones, guaranteeing a rigorous protection of the construction authenticity.

While in the first solution it is necessary to avoid the simple recovering of the ruins to their original status, in the second case a recover of the ruin as a scene shall be avoided.

Between these two alternative hypotheses, a different solution, the so called "critical restoration", has grown in the last decades: it corresponds to the respect of the superimposed layers. The methodology does

not have univocal pre-defined solutions, but adapts itself, case by case, recognising the knowledge (data from archives, analyses of the materials in situ, direct investigations) and the special and unique nature of the single building.

2 CASE STUDY BUILDING: HISTORICAL INFORMATION AND EXISTING SITUATION

The project concerns the ruins of the ancient Monastery of Salemme in Sanza, a small village located in the interior part of Campania, a region of the central-southern Italy. The monastery is located in a seismic area characterized by medium seismicity according to the Italian hazard zoning.

The monastic complex of the Saints Joseph, Peter and Paul was founded by Don Giuseppe Teutonico, son of Gaetano, from Salerno, and Agata Vittoria Barzelloni, from Sanza (as it results from the "Archivio Barzelloni") probably before the year 1720. This is the date of the altar sculpted by Andrea Carrara for a chapel and now located in the St.Vito's chapel. The naming of "Salemme" is probably due to the fact that it was used by monks of the Franciscan Order of Jerusalem.

Andrea Carrara, from Padula, also sculpted on 1742 the busts of the Saints Joseph, Peter and Paul, now located in the church of Santa Maria Assunta (resulting from the "Catasto Onciario" of 1753).

In the second half of the 19th century, one hundred years since the foundation, the complex was already abandoned and the chapel was used as burial, like the "extra-moenia" chapel of Santa Maria del Popolo.

The ruins include two small buildings tied together by a perimeter wall closing a large area probably assigned for agricultural use. The first building (A), more complex, was used for the monastic life: it consists of a prolonged portion and a number of rectangular rooms, one of which seems to be a small church. It is a 2-stories building with a 3-stories portion. The second building (B) consists of two volumes: a low volume, probably covered by a roof and used for recovering animals and a second volume, next to the previous one, showing the ruins of a 3-stories small tower, covered by a roof, with a top decoration. Figure 1 shows a general plan of the complex where the two buildings, A (the upper one) and B, can be identified. Figure 2 shows some sections of the existing buildings. Figure 3 reports the southern lateral view of the complex.

The walls are made of multi-leaves stone masonry (Figure 4). The exterior leaves are made of stone blocks roughly shaped, while the interior part consists of many little blocks.

The building has undergone strong decay phenomena in the last decades, due to the neglect status, and

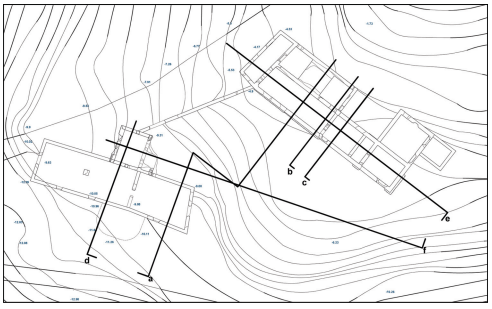

Figure 1. General plan of the complex.

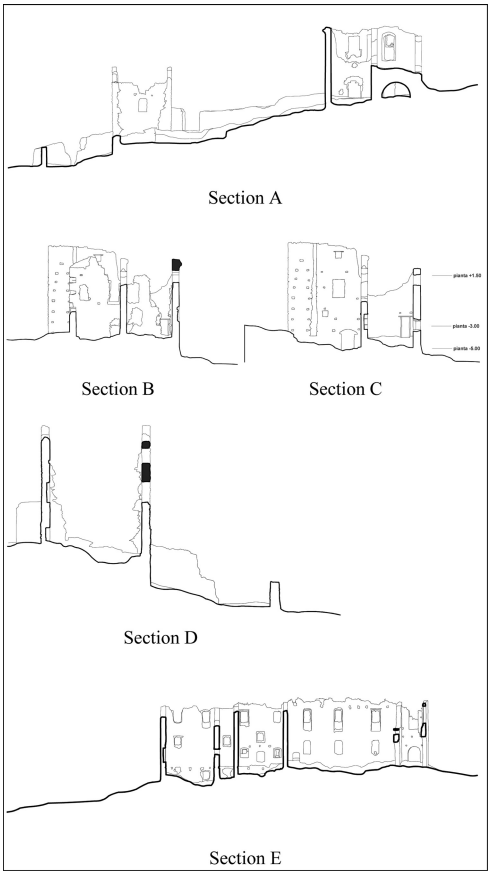

Figure 2. Sections of the existing buildings.

it appears as ruins (Figures 5, 6, 7). Failed portions occupy the internal spaces. All the roofs and wooden floors totally collapsed. Only some portions of the masonry walls stand, while large portions, especially the crowning/coping, collapsed. The lack of protection from the environmental and atmospheric agents caused the decay of the residual walls, particularly the

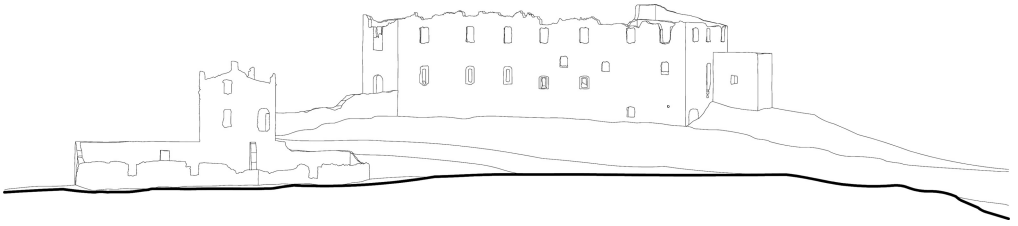

Figure 3. South view of the complex.

Figure 4. Detail of the multi-leaves stone walls.

lack of compactness, due to the loose of mortar. Also all the wooden architraves are lacking. The general stability of the walls is unsafe.

3 PROJECT FOR RE-USING

The Venice Charter (1964) stated that *"The conservation of monuments is always facilitated by making use of them for some socially useful purpose. Such use is therefore desirable but it must not change the lay-out or decoration of the building"*. In the present case, the rehabilitation project is a part of a larger project concerning the realization of the Centre for the Environmental Education of the "Cilento e Vallo

Figure 5. Porch of building A.

Figure 6. External view of building A.

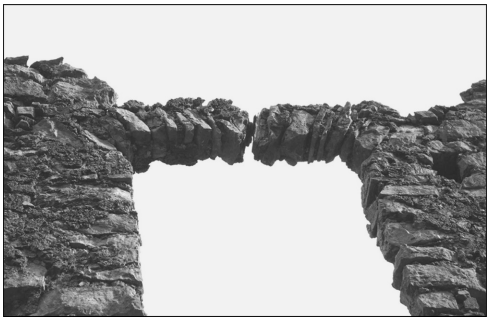

Figure 7. Statical criticity local situations.

di Diano" National Park. Within this project a number of different initiatives are provided, supporting a unique territorial complex in which the protection of the environment and the social and economic development of the activities related to the development of the park will harmonically coexist. Two areas were pointed out for pursuing the project goals: one, related to the urban activities, consists of an existing building previously hosting the Rangers' barracks; another one consists of the ruins of the so called Monastery of Salemme - Santa Maria delle Stelle, located at the slopes of the park's mountains.

The first initiative of the project to be put into effect concerns the construction of the Centre for the Environmental Education, composed by a school of journalism and by a number of information and learning activities, in the ancient Monastery of Salemme. The recovery of the ruins will allow for an information desk of the visitors, a didactic approach before the visits, a formation school of environmental journalism. The project solution hypothesizes a use of the Monastery even apart from the ordinary institutional activities: the didactic laboratory will allow holiday visits to the complex also to the inhabitants of the territory around, a small restaurant will allow a more comfortable staying. Moreover the complex will include a new building (called C) devoted to a conference hall, of about 100 places, promoting the fruition of the building over the use as school and information centre.

4 INITIAL CONCEPT SOLUTION FOR THE RETROFITTING

A preliminary design hypothesis provided the construction of r/c structures sticking to the existing masonry walls and relevant demolition and reconstruction works (Figures 8, 9, 10). This kind of work does not appear appropriate with the aim of the conservation of the historical portions of the building.

Since the Athen Charter (1931) it was recommended a *"judicious use of all the resources at the disposal of modern technique and more especially of reinforced concrete"* and specified that the *"work of consolidation should whenever possible be concealed in order that the aspect and character of the restored monument may be preserved"*, moreover it was recommended the adoption *"in cases where their use makes it possible to avoid the dangers of dismantling and reinstating the portions to be preserved"*.

The preservation principle is also reminded in the cited Venice Charter (1964): *"The process of restoration is a highly specialized operation. Its aim is to preserve and reveal the aesthetic and historic value of the monument and is based on respect for original material and authentic documents. It must stop at the point where conjecture begins, and in this case moreover any extra work which is indispensable must be distinct from the architectural composition and must bear a contemporary stamp."*

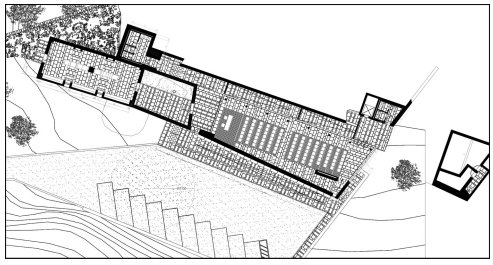

Figure 8. Initial project. Plan of buildings B and C.

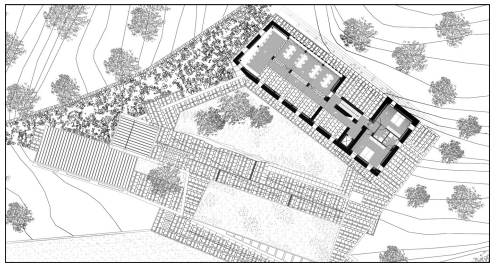

Figure 9. Initial project. Plan of building A.

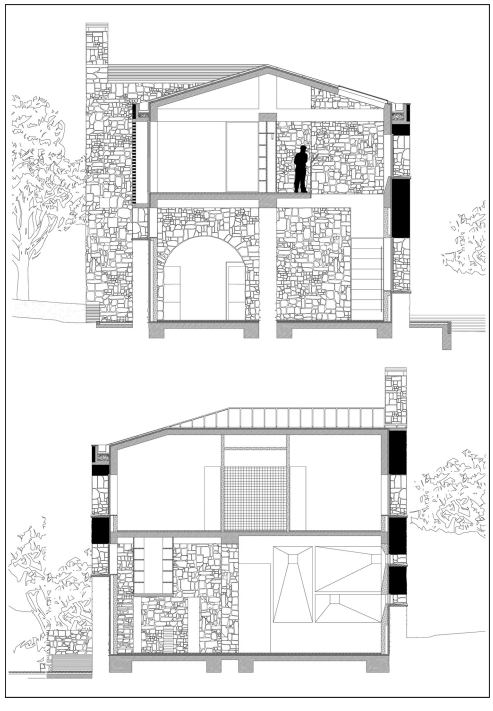

Figure 10. Initial project. Sections of building A.

According to this principle, the preliminary project was considered not feasible and therefore rejected

by the superintendence authority on the historical heritage.

5 CONCEPT SOLUTION OF THE FINAL RETROFITTING DESIGN

A completely new concept solution has been conceived. The building restoration provides for a number of works allowing for obtaining a significant increase of the static and seismic safety of the building considering the present situation of failure and decay. The typical provided works for each class of statical problems are presented in a following paragraph.

The seismic enhancement of the existing structures has taken into account both the *Codice dei Beni Culturali* (2005) and the *Linee Guida* (2006), that is the most recent Italian guidelines concerning the preservation of the cultural heritage, with particular attention to the constructions located in seismic areas. The primary goal offered by the provided works consists of the reduction or elimination of the main vulnerability causes and can be resumed in the following items:

- increasing the strength of the existing stone masonry walls;
- tying the building in correspondence to the levels of intermediate floors and roof;
- conferring a suitable flexural strength to the architraves.

The seismic enhancement is completed thanks to the interaction of the enhanced old structures with the new ones that guarantees:

- the behaviour of the floors as horizontal diaphragms;
- the sustain against the overturning mechanisms (1st mode mechanisms in general);
- the reduction of the wall length included between successive orthogonal walls;
- the effective connections between walls and floors.

A particular solution has been conceived based on the synergetic interaction between new and existing structure. The new project was carried out providing for the building of new steel and wooden light structures to be inserted within the fields defined by the in-plan alignments of the existing walls. The steel structure foundations allow for a minimum interference with the expected underground finding of graves and burials. The masonry walls will be strengthened by mortar injection and by the insertion of twin steel beams at the floor levels, across the wall thickness by means of passing-through injected bars. Special connection systems between new structures and old masonry walls allow for a triple function: to avoid the interaction in the vertical load bearing capacity, to avoid collapse mechanism orthogonal to the wall plane through the horizontal bracing effect of the steel frame, to use the horizontal load bearing capacity of the retrofitted and strengthened walls in their plane. Suitable technological solutions have been adopted allowing for the compatibility with the existing materials while evidencing the separation with the *existent*.

6 DETAILS OF THE DESIGNED SOLUTION

6.1 *Consolidation and strengthening of stone masonry*

The following works are provided for the consolidation of the existing stone masonry walls and their strengthening.

Demolishing of unstable portions. The situation concerns some vertical cantilevered walls and some unstable architraves.

Deep refilling of mortar joints. This work concerns all the walls in a generalised way and consists of taking away and restoring the mortar of the external portion of the joints among the stone blocks.

Injection of the elevation walls. All the walls are concerned by a lack of link and compactness in the depth. To overcome the lack of mortar, a generalized injection with fluid no-shrinkage lime mortar is provided. Ultrasonic tests will be carried out before and after the injection for evaluating its effectiveness in increasing the compactness.

Rebuilding/Adjusting the top portions and ruins. The top portions are rebuilt with masonry having the same characteristics (blocks and texture) of the existing one. The insertion of reinforcing steel bars is provided, so that the top portions will include a reinforced masonry tying beams.

Drilled steel connectors. Many L (angular) and T (intermediate) connections among walls are completely or partially lacking in continuity and do not give an effective solidarity and connection. In all these cases is provided the tying of the orthogonal walls by means of bars inserted within holes drilled in the masonry and injected with the same mortar used for the masonry injection.

Existing foundation strengthening. The existing masonry foundations will be strengthened by means of deep injection, slightly reinforced, performed in the foundation and bottom part of the masonry (Figure 11).

Top tying beam in reinforced masonry. The actual situation is characterised by the lacking of longitudinal link at the top of the masonry walls. Moreover, the most part of the walls are completely lacking of the top portion, already collapsed. A reinforced masonry tying beams is provided at the top of all the walls (Figure 12).

Intermediate steel tying beams. At the levels of the intermediate floors of the internal new structure longitudinal steel tying beams will be built consisting of two U-shaped steel beams, coupled through the wall thickness by means of anchoring bars injected in holes drilled in the masonry (Figure 13).

A multiple structural effect results:

- obtaining a longitudinal continuity of the walls at the intermediate level (at the walls' top, the reinforced masonry tying beam is provided);
- creating a connection system with the new structure for the mutual bracing against horizontal actions;
- tying effect at the floor level contributing to equilibrate some static horizontal actions (e.g. the pushes from the arches).

Closing of cracks. Many cracks are present, sometimes passing through and in some cases having relevant width. Different kinds of work are provided for the different situations:

- removing and repositioning of blocks along the cracks;
- mortar injection and tying effect given by the tying beams;
- connection by means of slightly reinforced injected holes.

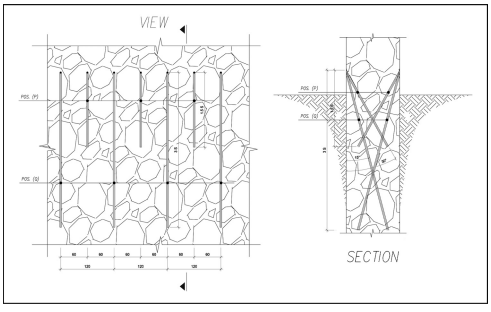

Figure 11. Consolidation of foundations.

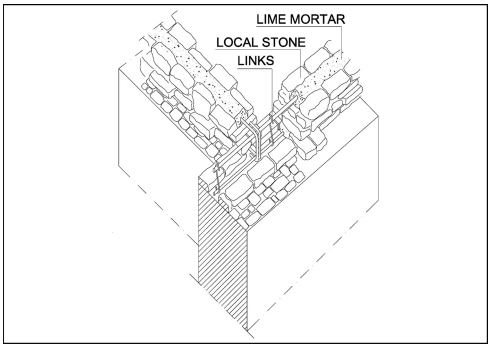

Figure 12. Top tying beam in reinforced masonry.

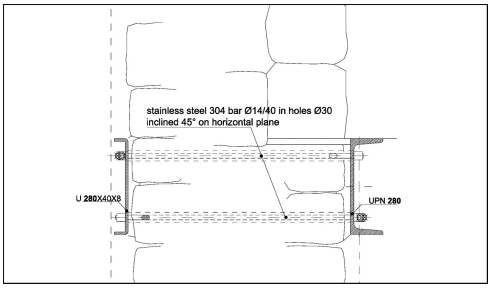

Figure 13. Intermediate steel tying beams.

Re-making up architraves. Almost all the opening are lacking of their architraves. They will be re-made up according to a flexural resistant arrangement consisting of steel beam covered by wood boards underneath.

Re-making up failed openings. In some cases the openings, not only are lacking in architraves, but are failed along their total perimeter. They will be restored rebuilding the stone masonry of the horizontal and vertical sides.

Closing niches and flues. The walls integrity will be pursued by the filling of the voids by effectively interconnected stone masonry having the same characteristics of the existing ones.

Re-opening pre-existing openings. Many old openings are present, closed with non-continuised infill masonry tables. If the opening shall be re-opened, the infill will be removed and the opening will be subjected to the works provided for the failed ones. If the opening shall remain closed, the same works provided for the crack closing will be applied.

Arches of the western porch and relevant ones. Figures 15 and 16 respectively show the situation of the porch of building A and that one of an internal arch. It is assumed that the insertion of the intermediate tying beams gives to the masonry the capacity to sustain the horizontal pushing forces of the arches. In some cases specific tying bars are provided at the base of the arch.

6.2 *New steel structures*

Considering the current status of the structures, that is particularly sensitive and critical due to the constructive typology, nature of the site, historical

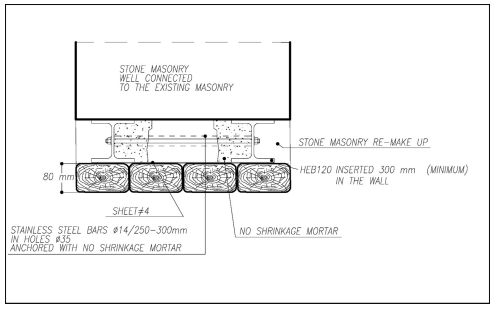

Figure 14. Solution for the new architraves.

destination, decay status, other witnesses not yet investigated, the new structures were designed as made of steel frames with wooden horizontal structures.

This typology, which guarantees punctual foundations, longer spans and more "connections" with the "existing", allows to reduce the risk to compromise the historical witnesses. In each internal area of the existing building, individuated in-plan by perimeter walls, only four base supports are present (at the corners), so allowing for the preservation of the ancient structures, both those already pointed out in the old chapel and the other ones still hidden.

The framed structure consists of columns and beams having standard I-shaped section. The floors are made of wood with single-aligned or double-aligned beams. The horizontal bracing is given by crossed tying bars located in all the rectangles of the structural grid. Figure 17 show a plan of the building A with the internal structures. Figure 18 show a section of the same building with relevant details.

Figure 15. Arches of the porch of building A.

Figure 16. Typical arch at the interior of the building.

6.3 *Synergetic interaction between new and existing*

The new and the consolidated existing structures perform together in a synergetic way allowing the enhanced performance of the building against the seismic attacks.

Special tools (Figure 18) are arranged for connecting the floor beams of the new framed structure with the steel tying beams running at the interior of the stone walls at floor level and with the top reinforced masonry tying beams. They allows for free mutual vertical displacements, while the lateral displacement are blocked by the bolted connection.

The complex of the new and existing structures perform in different ways with respect to the lateral and vertical actions. The vertical loads of the new structures, both permanent and live, are carried by the steel frame and transferred at the base by its columns. The masonry walls carry their dead load. The behaviour against the lateral loads is synergetic.

According to the scheme reported in Figure 19, the seismic actions on the walls, orthogonal to their plane, are supported by the horizontal elements of the steel frame, thanks to the connectors.

The lateral actions of the steel frame are partially supported by light vertical bracing system, included in the steel frame, and partially transferred to the wall parallel to the lateral actions (Figure 20).

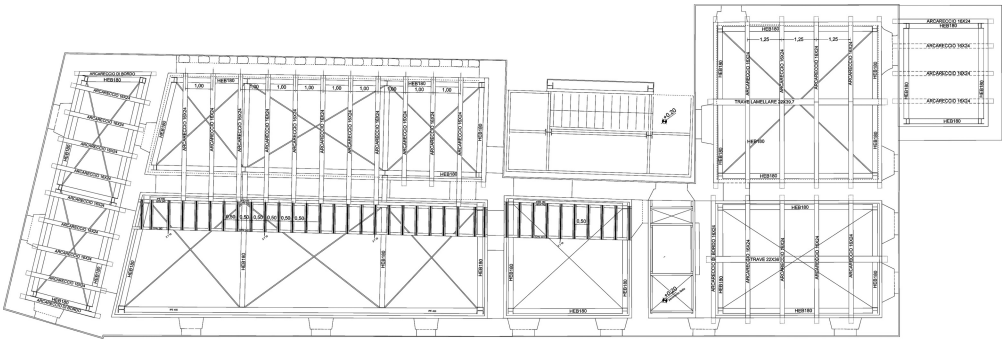

Figure 17. Plan of 1st story of building A.

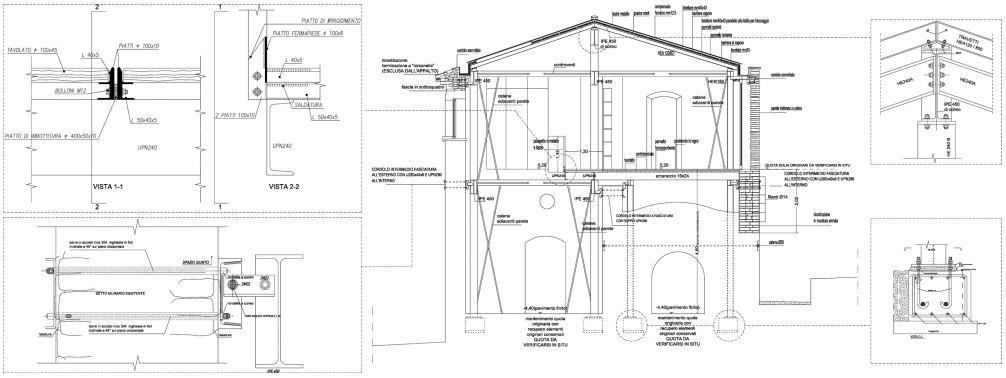

Figure 18. Section and details of building A.

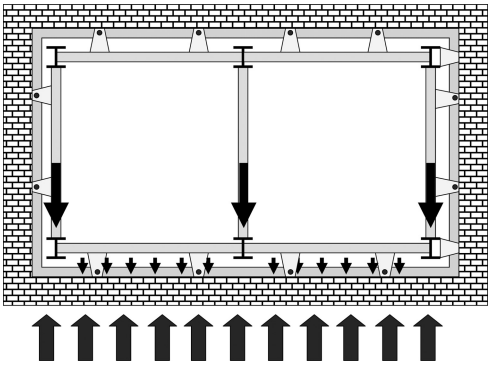

Figure 19. Transfer mechanism of seismic forces to the steel structure.

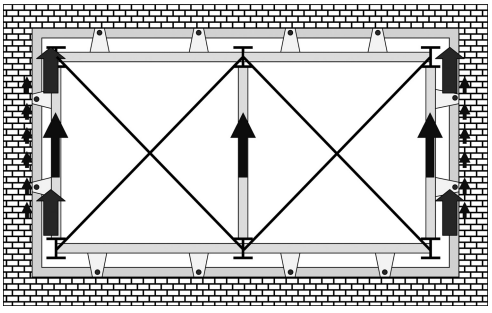

Figure 20. Transfer mechanism of the seismic forces to the masonry.

7 CONCLUSIONS

A restoration project aimed at the re-use of an old monastery, at present in a ruined condition, has been carried out providing for new technological solutions allowing for the preservation of the existing structures even decayed.

The design solution provides for the insertion of new steel structure with wooden floors at the interior of the existing stone walls, suitably restored and integrated.

The two systems, the existing one and the new one, work in a synergetic way with respect to the vertical loads, but, most of all, against the forces induced by the seismic action.

The new structures supply the missing performances: diaphragm behaviour of the floors and capacity against the overturning; the existing structures contribute to sustain the seismic forces, thanks to their high in-plane stiffness and strength.

The adopted solution show the possibility offered by the synergetic contribution of the existing and new structures, while evidencing the separation with the existent construction.

ACKNOWLEDGEMENTS

The Comune of Sanza is the owner of the buildings. Arch. Mauro Marzullo is in charge of the project. Soc. Cooperativa EdilAtellana is the contractor.

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