

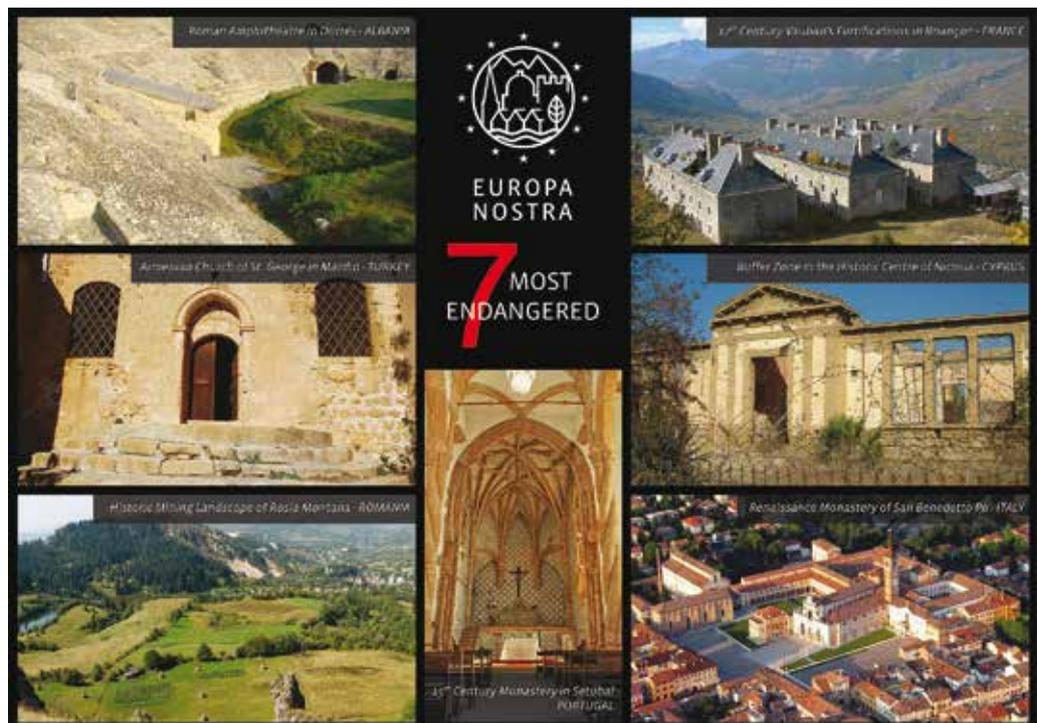
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■ The reparation and the seismic strengthening of the Monastery of “San Benedetto in Polirone”

The Monastery of “San Benedetto in Polirone” is a monumental complex whose origin dates back to the eleventh century. After 6 years of restoration from 2005 to 2011, The Municipality of San Benedetto Po, owner of the building, was using its spaces for several different public purposes such as a museum, public library, hostel, space for conferences, storage etc. The previous interventions aimed mostly to an overall refunctionalization, to the requalification of technological systems and to the restoration of historical plasters and decorations, and partially included even structural strengthening (because the area wasn't considered seismically exposed).

After the earthquake occurred in may 2012 in Modena and Mantova, the complex was badly damaged and, in some local portions, was risking to collapse. The earthquake hit the hardest in the portions of the complex called “Ala Giorgi” and the “Secolari” cloister, where the structural situation was already critical and no restoration was accomplished yet. In December 2013 the Monastery was appointed by Europa Nostra as one of the 7 most endangered monuments in Europe.

The first priority was to secure the structures from further deterioration and collapse. Since the building is entirely scheduled under the protection of the Superintendence for Architectonical





The provisional reinforcement of the arches in the "Secolari" cloister



The provisional reinforcement of the columns of the main entrance of the museum in the "Secolari" cloister



The provisional strengthening of the "Ala Giorgi"

Historic Heritage of Brescia, Cremona and Mantova, every single intervention on the monument needed to be discussed and authorized in advance. During every step of the work, the group has developed a continuative discussion and exchange with the responsible of the Department in charge of the complex, in order to optimize the effectiveness and the quality of the decisions.

Since the first weeks after the seismic event, many urgent interventions were accomplished:

The arches in the "Secolari" cloister and the main entrance of the museum were reinforced with wooden provisional structures specially designed to maximize their efficiency in accordance with the context. The lightweight decorated ceiling of the "monumental stair" and of the "Monastic Library" were protected and sustained with dedicated punctual scaffoldings. The "Ala Giorgi" – already structurally unstable before the quake – needed to be strengthened with provisional nylon cables, wooden trusses and local supports of arches and doors.

After the overcome of the emergency phase, with the structures temporarily safe, the team began to deal with the design of the reparation and seismic consolidation of the whole complex. The peculiarities of each area of the Monastery, the modification occurred during its history and the different building techniques involved, requested an accurate and almost tailored approach in full respect of the great artistic value of the building.

The dimensions of the complex and the haste to enhance the strengthening work pushed the Municipality to split the interventions in separated portions with different contractors, but under the same unified technical supervision. The interventions described in the following lines are only part of the whole reparation work that will need more time and much more important funding to be completed.

ALA GIORGI

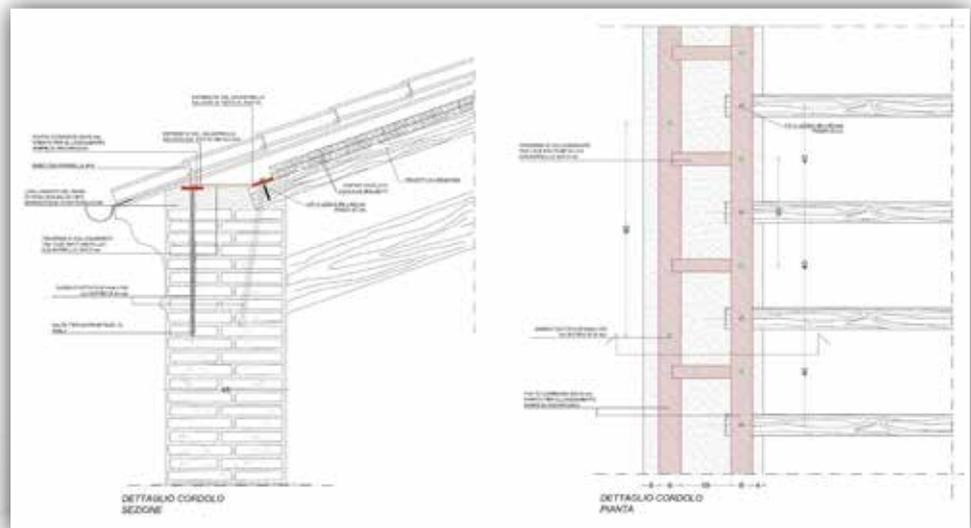
The area of the "Ala Giorgi" was heavily damaged by the earthquake because of preexisting

structural weaknesses. The roof was the weakest portion in consideration of the lack of connections among each structural element and was the only area without decorated plasters. The wooden structure was completely restored with metallic reinforcements and with the insertion of new dedicated metal-ties. Such interventions were necessary to connect the perimetral walls with each other and with the wooden trusses of the roof. After these works, the roof was refurbished and completed with thermal insulation, a new waterproof layer and the reallocation of roof tiles in accordance with the surroundings.

Other new tie-rods were located at the first floor to contrast the horizontal push of vaults and arches. The foundations in the underground rooms were reinforced with bricks and mortar with the same dimensions and peculiarities of the existing.

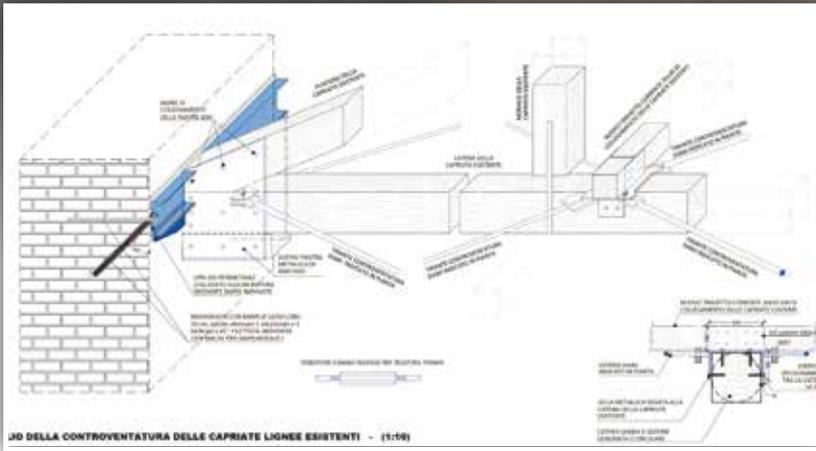
Technical detail of the interventions on the top of the perimetral walls.

The interventions on the top of the perimetral walls.





Detail of the installation of a single metal joint on the wooden trusses of the roof.



Project detail of the strengthening system



General view of the roof of the Refettorio during the implementation of the work

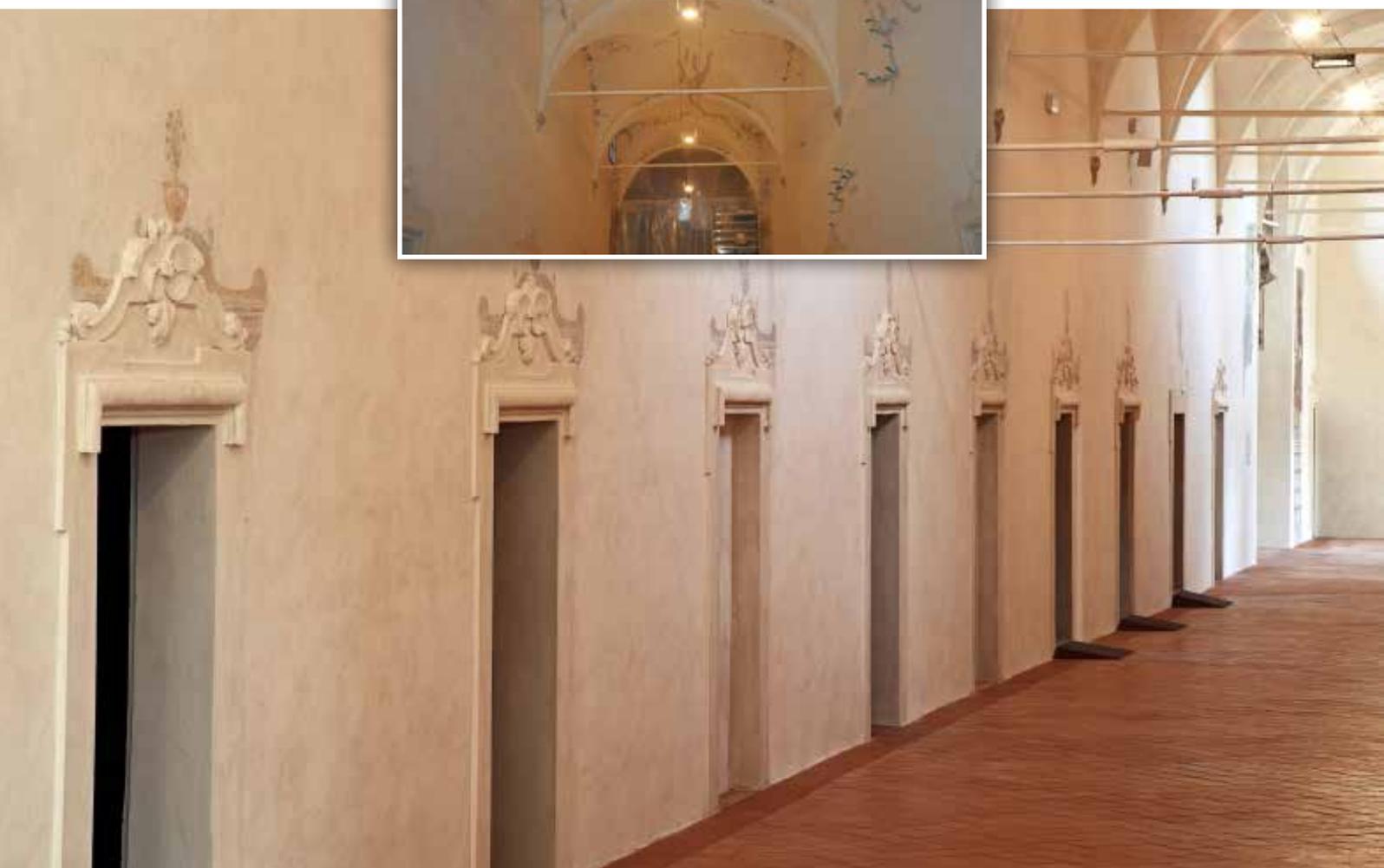
REFETTORIO

The building of the “Refettorio” is a large and empty room composed of four spans with cross vaults each almost 15 meters wide. The first cross vault collapsed almost a century ago, while the remaining three resisted even the earthquake. The survived vaults exposed large and dangerous cracks after the quakes, mostly concentrated in the perimetral portion, inducing to fear the possibility of their collapse. Such vaults were realized with a heavy double layer of bricks, and after an accurate analysis were considered stable. The problem was identified in the perimetral walls that needed to be better connected mainly in the top area. The intervention proposed start off from the reparation of the cracks in the vaults with appropriate injections and on the reinforcement of the horizontal connection among perimetral walls. Such connection will be realized thanks to a new wood and metal structure. A new metal ring made with UPN 200 will be connected with the existing walls just under the roof, and a series of new metal joints will be applied between the existing trusses and the metal ring. Each joint will be connected with metal cross-braces in order to set several smaller spans among the original larger ones. The principle of the intervention is quite simple and is based on the idea that smaller spans have a much better behavior than larger ones in case of earthquakes.

The simplicity of the principle didn't actually follow the realization; in fact every existing wooden element was different from each other and differed in height, size, position and state of preservation. Every single joint needed to be verified, controlled and often adapted to meet the specifications requested. In many cases the structures were modified and adapted during the history and offered different dimensional configurations. Moreover, the area of intervention (between the roof and the vaults and among the existing trusses) was particularly difficult and uncomfortable because of the small operative spaces, the lack of light and the sloping floor. Many unexpected chances occurred during the development of the work, but finally the strengthening system was completed.

After the completion of the structural interventions and the consolidation of the cracks with special mortar injections, the internal decorated surfaces will be restored in order to return the overall aspect.

The reparation of the cracks with mortar injections during and after the interventions



MUSEUM

The restoration of internal decorated and historical surfaces of the area of the Museum was completed only from a short time before the earthquake. The interventions were focused even on the architectural reorganization and on the requalification of the internal systems, but they almost didn't affected the structures. Only portions of the masonries were consolidated with mortar injections and with the reconstruction of small portions.

The damages in the Museum where mainly concentrated in the corridors along the "San Simeone" cloister. The corridors are characterized by high cross-vaults made of bricks above which there is the wooden structure of the roof.

After an accurate analisys of the existing situation - including the definition of every local and global weakness, the team designed several interventions mainly regarding the strengthening of the roof.

The vaults along the corridors presented widespread superficial and deeper cracks caused by the seismic force. Every crack was accurately opened along its entire length, trying - where possible - to preserve original plasters. Then, a special consolidating mortar was injected through the cracks in order to recompose discontinuities.

The material filling the sides of the vaults was accurately removed and replaced with a lighter material (to enhance the overall seismic behavior). New wooden elements were connected to the perimetral top of the walls over the corridors to create a sort of ring. The ring was interconnected with special metal joints to the existing trusses of

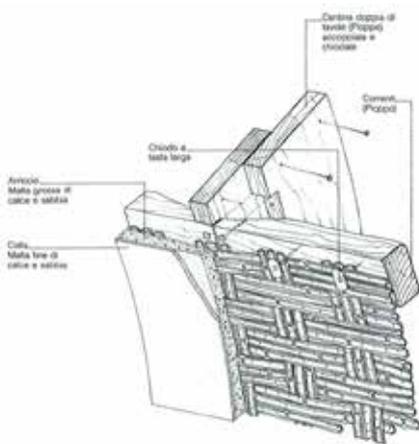
General image of the strengthening interventions on the roof over the "Scriptorium"



General image of the strengthening interventions on the roof over the corridor of the museum

Project detail of the interventions





The building technique of the lightweight ceiling of the monastic library

the roof. Thanks to these new metal elements, two couples of cross-braces were inserted just above the vaults and higher under the roof.

The general aim of the intervention is to enhance the connection of the walls to acquire more stiffness and reduce the horizontal push of the vaults. As it was for the Refettorio, even for the area of the museum, the complexity of the interventions was depending on the impossibility to apply a standardized approach: in fact every joint needed to be personalized and adjusted because of the singularity of each element.

After the completion of structural intervention, all internal surfaces will be cleaned and accurately restored.

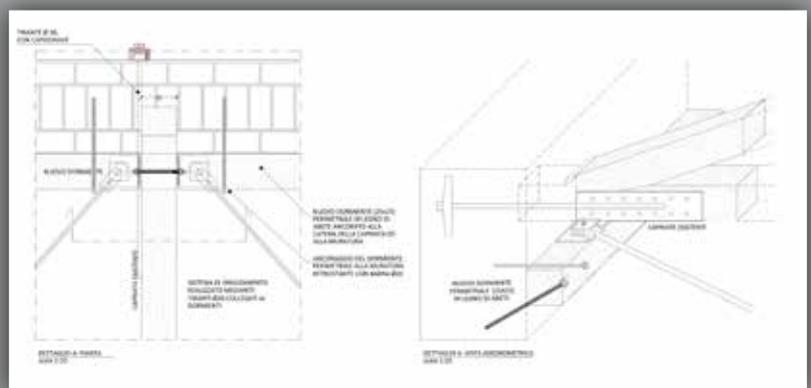
MONASTIC LIBRARY

The ceiling of the “Biblioteca Monastica” is a lightweight structure partially hanged to the upper roof trusses, made of vegetal weaved fibres supporting the decorated plaster. Such light structure has suffered heavy damages and a partial collapse after the earthquake, because of the peculiarities and weaknesses of the building technique itself. The lightweight and elastic structure of the ceiling seismically behaved differently from the heavyweight perimetral walls, thus resulting in a partial collapse and in widespread cracks. The intervention proposed consists in the realization of a wooden ring, fixed on the top of the perimetral walls and connected with the existing trusses to improve stiffness. In addition the design team proposed the insertion of a couple of new plywood trusses side by side with the existing bearing structure of the ceiling to reinforce it and connect it to the surrounding walls.

After the completion of the reinforcements, the internal surfaces will be completely restored, the decorations will be cleaned and repaired and the collapsed portion – if possible – will be reinstated.



Detail of the reinforcement of the ceiling

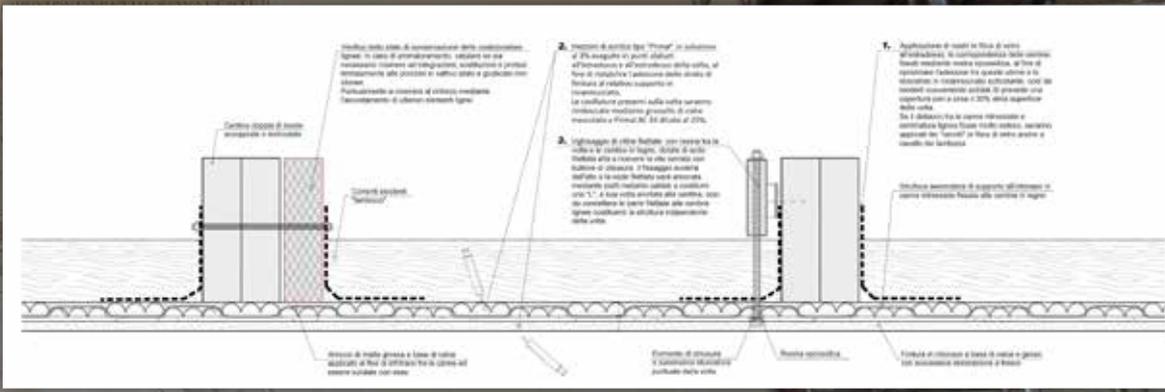
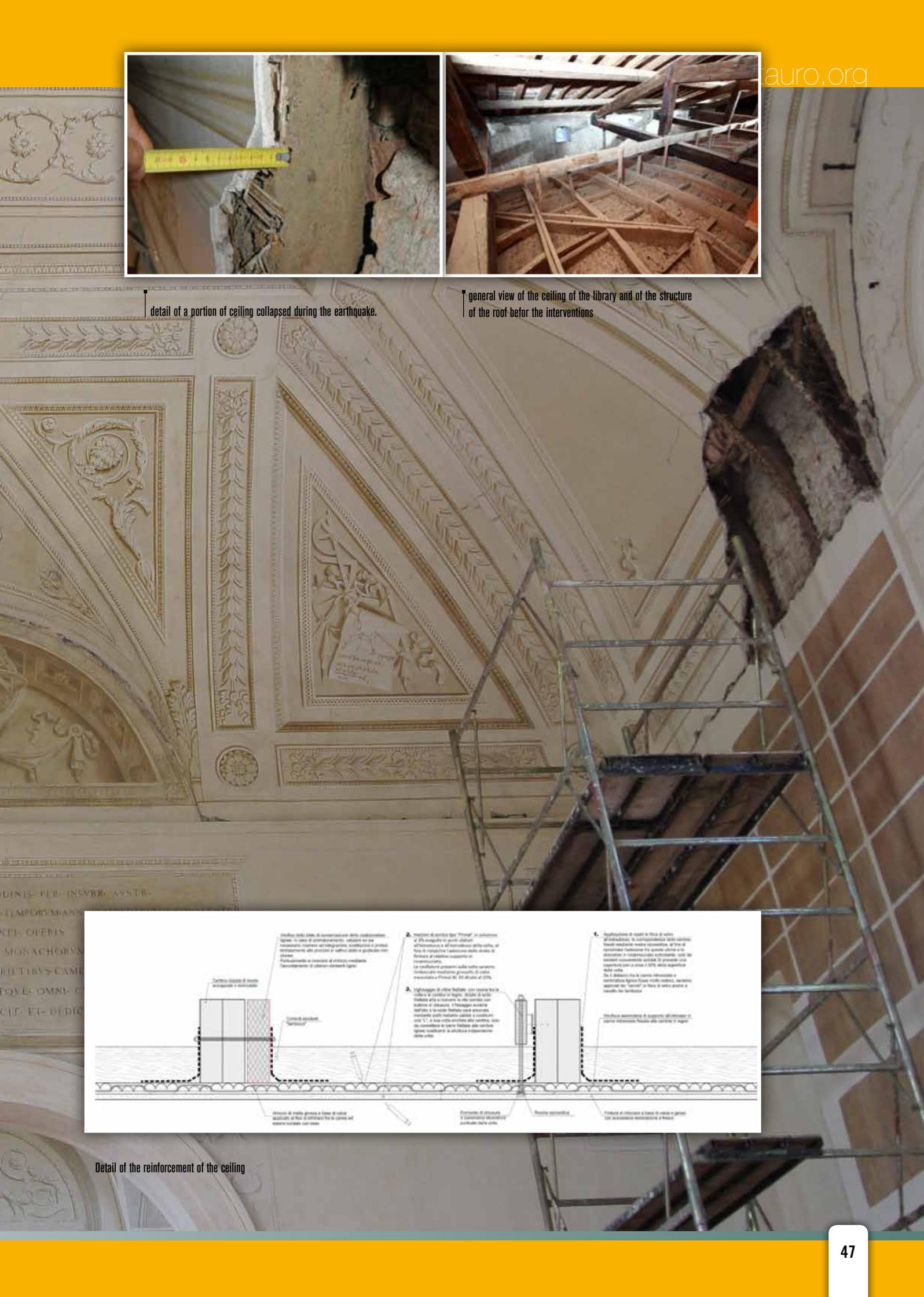


Detail of the reinforcement of the trusses sustaining the roof of the monastic library



detail of a portion of ceiling collapsed during the earthquake.

general view of the ceiling and of the structure of the roof before the interventions



Detail of the reinforcement of the ceiling