GRUPPO iar srl

RESTAURO MONUMENTALE E ARCHITETTONICO
CONSOLIDAMENTO STRUTTURALE

ASSISI
UPPER BASILICA
OF SAN FRANCESCO

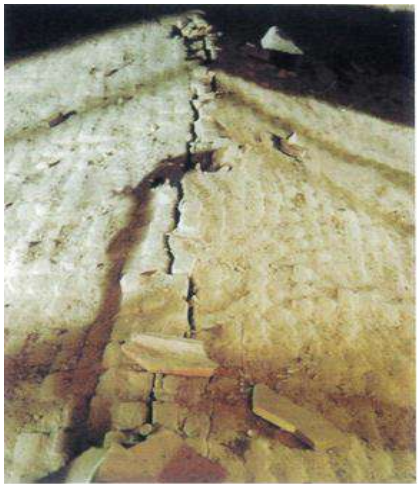
THE CONSOLIDATION OF THE VAULT DAMAGED BY THE EARTHQUAKE

EARTHQUAKE DAMAGES

On 26 September 1997 a violent earthquake inflicted deep wounds on the Basilica. Collapse has affected two points of the vaulted roof of the church resulting in the death of four people and the loss of three sails frescoed with precious paintings: the one depicting the evangelization of Judea by St. Matthew, of Cimabue, placed at the crossroads between the main nave and the transept, and the sails of San Girolamo, painted by Giotto, placed at the beginning of the nave just above the entrance. The earthquake also led to very serious injuries to the surviving vaults, which made the Basilica vulnerable even against normal atmospheric adversities such as a strong wind or a thunderstorm. The situation was therefore very critical, given that the safety of those who were working inside could not be guaranteed: the safety of the vaults and their consolidation then became the priority, also to avoid the loss of other precious frescoes.

CAUSES AND DAMAGES

The structures affected by seismic events retain their memory, therefore being the area with high seismicity, the vaults have undergone progressive weakening and loss of shape, the latter very dangerous on structures that owe their bearing capacity precisely to the conservation of their design geometry.
At the beginning of the works many signs of previous structural discomfort were noted, with clumsy attempts to restore: this is the first serious reason to explain the collapse. Over the centuries, the waste material from roof renovations has been accumulated on the side walls, inconsistent material weighting 1,200 tons; as a result of the acceleration (about 0.2 g) caused by the earthquake, a horizontal thrust was generated on this loos material, not bound by the mortar, which caused the loss of the vaults ribs curvature forming a hinge towards the centre line and collapsed dragging the sails with them. The location of the collapses near the facade and the transept is probably due to the higher rigidity of these structural elements compared to that of the nave itself, firmly joined to them.



(Photographs illustrate the state of the vaults after the eartquacke)

ADOPTED SOLUTION

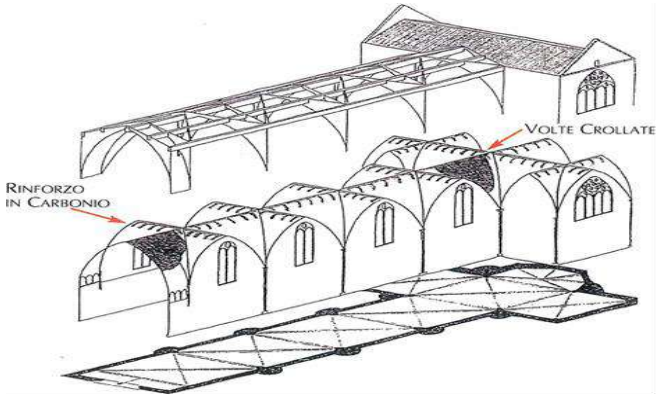
The surviving vaults were in a very precarious situation: there were large cracks distributed both on the extrados and on the interior; the original curvature was also lost in several areas. Since there was no possibility to intervene quickly from inside the nave due to the risk of collapse, it was decided to build a walkway suspended from the roof, in the space between it and the vaults with the dual function of allowing inspection and creating a base of work for the consolidation of the vaults to the extrados.

The design philosophy that inspired the intervention of urgency to make the vaults safe was to tie the structure in all its parts, restoring its continuity compromised by the cracking conditions state through the creation on the extrados of an exoskeleton able to absorb new and dangerous solicitations (also because seismic shocks continued to occur).

This exoskeleton had to be light in order not to add weight to the structure, elastic, to allow further small adaptations of the vaults, obtained with the use of a “drapable” material, able to adapt itself to the irregular shape of the extra dossal surface.

For all these reasons, **Carboniar®** system (Carbon Fiber Sheet Tapes and epoxy resin) has been utilized. Carbon fiber sheet enjoy an exceptional 4,900 MPa tensile strength and very low weight (1,8 kg / dm^3).

In favor of the intervention was the experience acquired in the design and implementation of a similar intervention, on a Palladio villa in Caldogno (Vi), in collaboration and with the approval of the competent Fine Arts Superintendency, who had indicated among the project inputs also the need not to damage in any way the underlined frescoes; this intervention was presented in May 1997 in Orvieto at the 5th National Congress of the ASSIRCO Association (Italian Association for Construction Recovery and Consolidation).



(Scheme of Carbon ribbons positioning on the vaults)

OPERATIONAL PHASES OF THE INTERVENTION

The intervention was carried out according to the following application cycle:

· removal of the large amount of filling material in the kidney area of the vaults;

· feeling of cracks with a special salts free mortar to limit as much as possible the damage to the frescoes; however, every precaution had been previously taken, under the guidance of the I.C.R. (Central Institute for Restoration), by inserting as much as possible, in the lower part of the cracks, a strip of polyurethane, with the sealing function;

· thorough cleaning of the substrate, by suction of dust and surface debris;

· impregnation of bricks with diluted epoxy resins, to facilitate their penetration and to achieve a more homogeneous and deep anchoring through the creation of the so-called "epoxy needles";

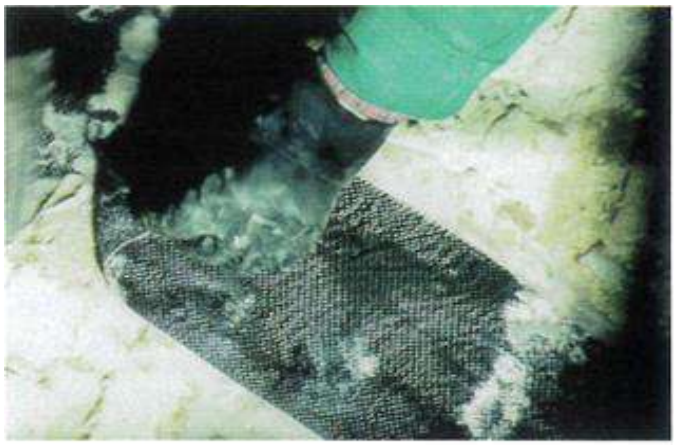
· regularization of surface unevenness by the utilisation of epoxy mortar, to fill the cavities of the brick courses.

· laying of carbon fiber on previously prepared areas;

· grouting of the edges with elastic epoxy paste to improve the adhesion of the carbon in the perimeter area;

· final saturation with solvent-free epoxy-polyurethane resin to complete the reinforcement system.

Among the various design inputs there was also that of the breathability of the frescoed surfaces: for this reason, the carbon fiber sheet tapes have been placed applied at 30-40 cm from each other, thus avoiding total coverage. About 800 linear meters of carbon sheet tapes have been applied, with a weight equal to just over 1% of the weight of the vaults.



(Some application phases of the carbon fabric used to sew up the cracks)

HISTORICAL CONTEXT

"Francesco, go and repair my church, which as you see is in ruins".

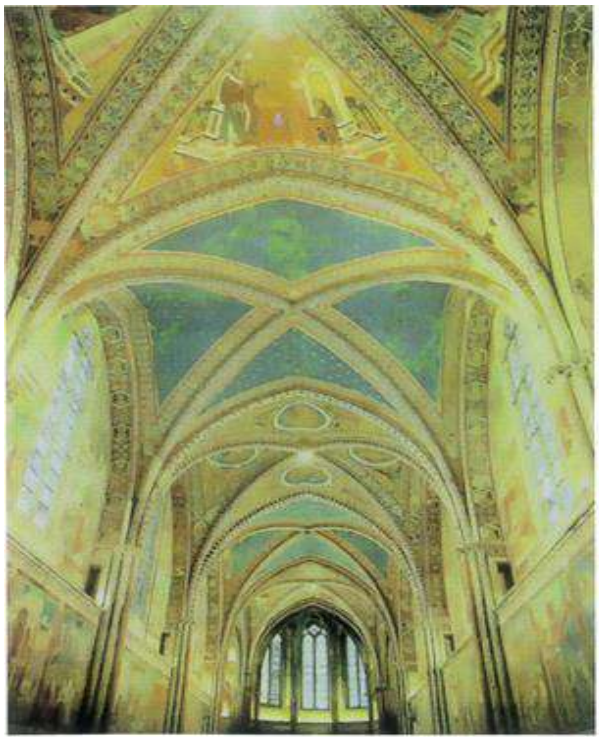
So spoke the Crucifix at San Domenico church, when in 1205 Francesco, a small man with an unkempt beard and suffering eyes, wandering through the countryside of Assisi, discovered it abandoned and in ruins.

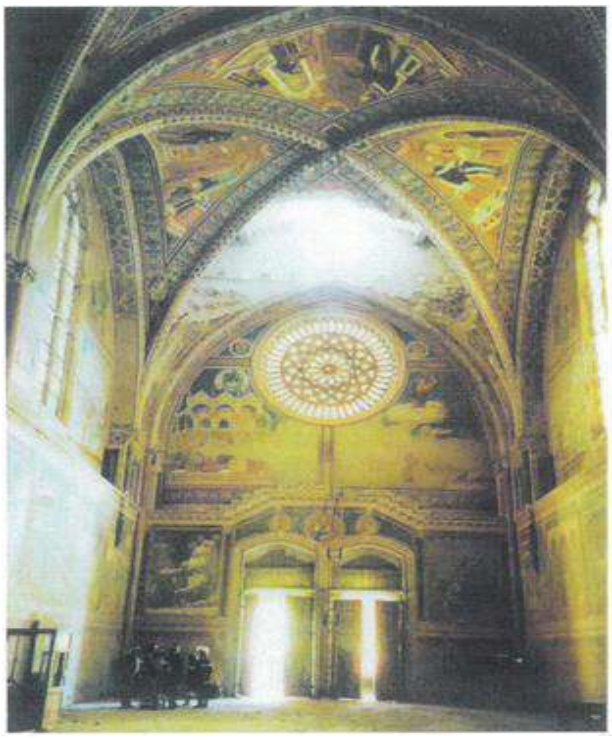
After 792 years, the Basilica dedicated to the Saint of Assisi is the church that risked the collapse shacked, on September 26, 1997 by a violent earthquake that caused deep injuries to the complex built on the slopes of Colle dell'Inferno.

The church whose first stone was posed by Pope Gregory IX on 17 June 1228 (on the project of friar Elia, theologian and architect, successor of San Francesco at the helm of the Order), planned on two sovrapposed levels from the beginning, one for the solemn celebrations, the other for the veneration of the Saint, buried inside a crypt excavated into the rock.

Among the first examples of Gothic architecture in Italy, it was the most important building site of the thirteenth century and, as such, brought together the greatest artistic talents of the time: Cimabue, Jacopo Torriti, Giotto, Simone Martini, Pietro Lorenzetti worked there ...

Here, thanks to their genius, the modern way of painting was born, a new language that overcomes the Byzantine stereotypes to open the doors to subsequent Renaissance inventions.





(The main nave before and after the earthquake)

GRUPPO iar srl

RESTAURO MONUMENTALE E ARCHITETTONICO
CONSOLIDAMENTO STRUTTURALE

67049 Tornimparte (Aq) - Loc. Piè La Costa - Via delle Sette Fonti, 14
Tel. 0425 417217 - Fax 0425 410115 - info.gruppoiar@gmail.com