THE MIRACLE OF ASSISI

by Alberto Balsamo, Umberto Battista, Natasha Calandrino and Renato Soffi

Friday, September 26, 1997, dozens of earthquakes devastated Umbria and the Marches, two regions in the very heart of Italy, killing 11 people and injuring 126. The tremors caused incalculable damage to the area's art treasures, including frescoes by Giotto in the Basilica of St. Francis in Assisi. Now that the fear and pain of those days have subsided, thoughts have turned to rebuilding and restoration: rebuilding houses, schools, churches and entire villages, so the people who live there can resume their normal lives as soon as possible, and restoring this rich artistic heritage to its former beauty for all of us to enjoy.

PHOTO 1

Photo Agenzia Scala

From Hell to Heaven

There was a story already going around in the twelfth century that St. Francis himself had pointed out the exact spot where he wanted to be buried. It was there that the church housing his remains would eventually be built, along with a monastery for his fellow monks. Situated "in quondam voragine", on the high cliff that now, as then, forms the northwest side of the hill-town of Assisi, the Franciscan complex is built on a site whose distinct topography is determined by the steep incline of the slope.
The place was notorious because from time immemorial criminals were tortured and put to death on the gallows there, earning it the name of "The Hill of Hell". Erected in the first half of the 13th century, the monumental complex of St. Francis consists of the two Basilicas, oriented on an east - west axis, and the Monastery which encloses the body of the church for almost its whole length (Photo 1).

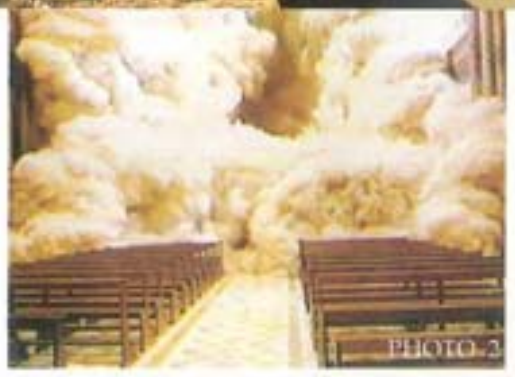
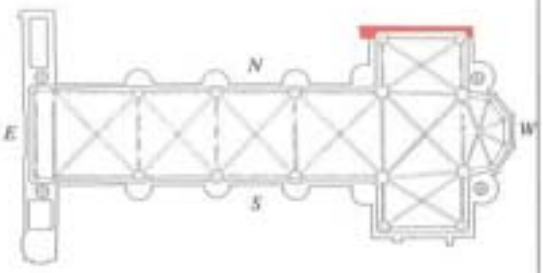


PHOTO 2

The church of St. Francis in Assisi is a marvelous example of Italian Gothic that contains frescoes by the greatest painters of the thirteenth and fourteenth centuries. The architect, Friar Elia, took advantage of the topography of the site (re-baptized "Hill of Heaven" because there lies the body of St. Francis) to create a soaring two-level structure with both levels laid



out on an identical plan: the Lower Basilica, to be used as a mausoleum, and the Upper Basilica, that was expressly designed to receive crowds of pilgrims. The most important artists of the time were enlisted to paint works in the Basilica complex: Cimabue, Giotto, Simone Martini, the Lorenzetti brothers... a priceless heritage that was severely damaged by the deadly earthquakes of September 26th. We were able to see live on television not only the tragedy of those left homeless by the quakes but also the collapse of the vaulting in the Upper Basilica (Photo 2), making it once again the Hill of Hell.

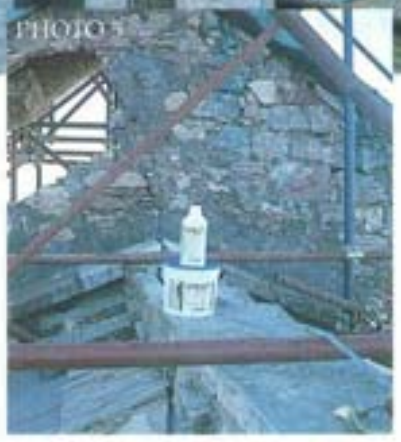
Government Commissioner Antonio Paolucci implemented a plan for assessing the damage caused by the earthquake so that immediate action could be taken to eliminate hazardous conditions and prevent further destruction of the artistic heritage.

To do so he needed the help of the latest and most sophisticated technology in a perilous race against time.

Ongoing sussultory and undulatory vibrations continued to traumatize many areas of the Franciscan complex, severely weakening its stability. With the clock ticking and fearing more after-shocks, technicians began the most pressing work needed to prevent the collapse of the gable of the left transept and the vaulting of the Upper Basilica, with its frescoes by Giotto and Cimabue.

PHOTO 4

PHOTO 3



The race to save the gable

The first problem to be tackled was preventing the collapse of the gable at all costs.

Since it weighed between 70 and 100 tons, the consequences could have been deadly if the gable had fallen through the roof of the Basilica.

This triangular piece of stone was by now little more than a shell, with certain sections that had previously measured 80 cm reduced to a mere 20 cm, and pockmarked and eroded from the recent pelting rain (Photo 3).

At this point the gable could not have withstood further shocks and might have collapsed with the slightest movement.

On October 14 at 11:40 a.m. the desperately needed repairs were begun.

The crew knew that the gable could not be shored up from below without risking lives, so with the help of a crane with an arm 50 meters long, they placed an enormous steel-skeleton frame of mesh and tubing over the gable to prevent it from collapsing (Photo 4).

The operation was not successful,

PHOTO 6

however, because the stone was by now ready to crumble.
The remaining sections had to be reinforced before installing the counter-gables which would have to support the structure.
The technology needed had to provide excellent bonding to the substrate, hardness, and high resistance to abrasion.
The solution was achieved using Mapei products (Photo 5).
With PRIMER EP, an epoxy primer with very high bonding strength, a preliminary waterproofing was applied to the stone and the mortar bed. The monolithic repair of the damaged structure was done with a spray application of EPOJET, a fluid epoxy resin (viscosity lower than 380 cP) that has excellent dielectric properties and high mechanical strength (Photo 6). At 12:30 a.m. the mission was accomplished: the gable of the basilica was safe.
"This extraordinary achievement," declared Commissioner Paolucci, "is proof that the Italian technical genius, know-how and craftsmanship exemplified by those who built this Basilica lives on in these men." It was an all-important step in safeguarding the house of St. Francis, but the emergency was not yet over.
Another aftershock on October 7th was the coup de grâce for many structures that had already been seriously weakened. On September 26th the dome-vault over the apse of the Upper Basilica collapsed, taking with it all trace of the "St. Matthew in Jerusalem" fresco by Cimabue. The dome- vault of the first bay and the sub-arch connecting the vaulting with the counter-façade also gave way, partially obliterating the work that Giotto had painted at the age of 25. (From 1290 to 1295 Giotto painted several frescoes of biblical scenes in the Upper Basilica.) The fresco of Saint Jerome and the Scribe that was part of the "Four Doctors of the Latin Church" series (Photo 7) was pulverized, causing the death of two friars and two technicians from the Superintendency who were assessing the nature of the damage and checking the structure's stability (Photos 8 and 9).

Many repairs were performed on areas that were in imminent danger because the static balance of the vaulting was seriously weakened.
The most urgent task was securing the groin of the collapsed vaulting in the first bay which jutted out dangerously several meters into space without being anchored.
The fresco underneath had to be completely protected from any debris that might be dislodged during the salvage work, despite the fact that the groin had many cracks and in some places was split clear through.
These cracks could have allowed adhesive to bleed into the extrados. In addition to that, the entire vaulting system had to be repaired. It had broken away from the side walls of the basilica and was very badly damaged along its whole length. These cracks would only get worse with time.
The repair work had to be done in such a way that no added weight would be put on the structures in question because they were no longer anchored at any point. Putting any more stress on them would have made the rest of the vaulting collapse, along with the fresco underneath. Moreover, an immediate decision had to be made as to the type of repairs that were needed. Work would have to get started within a few days because without eliminating this hazard, the job of shoring up the rest of the Upper Basilica from below would be impossible.

PHOTO 12

PHOTO 11

A catwalk built for two

A hanging catwalk made of metal pipe was anchored to the roof, running the length of the center of the Upper Basilica, so that the extrados of the vaulting could be repaired from above. The catwalk could be reached through a rose window, called the "eye", which is cut high up into the front wall of the gable (Photo 10). This catwalk was of vital importance to the outcome of the operation and made it easy to inspect not only the vaulting but the whole Upper Basilica (Photo 11).

PHOTO 10

The working platform then had to be widened by suspending metal scaffolding from it. This enabled the extrados to be repaired from above, with the men working lying face-down, in a not very comfortable position.

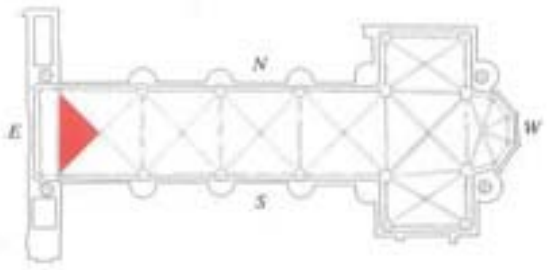
The repair operation proposed by S.A.C.E.N. S.p.A. and MAPEI was given enthusiastic approval. This involved using a modern technique combined with composite materials instead of cement based materials. Resins were used for integral structural bonding along with sheets of composite material, FRP (fiber reinforced plastic), that had to be artfully placed along the pattern of cracks. This technique allowed more than 15 sq. m. of Giotto frescoes to be anchored, along with the rest of the vaulting system. Using resins made wetting the substrate (the extrados of the vault) unnecessary, along with the undesirable consequences it might have caused, e.g. washout, re-activating stable chemical phenomena, endangering the fresco underneath, etc.).

A delicate operation

The job of cleaning the extrados of the vaulting was begun on schedule on October 22. This extremely delicate stage involved removing dust and loose material with painstaking care in order to prepare a solid substrate for the next phase (Photo 12). The work had to be done lying down on the platform, since walking on the vaulting was out of the question, making the cleaning difficult. It was also dangerous because the area being repaired was itself so precarious. Yet it was indispensable, as it made deeper evaluation of the actual condition of the area possible. A blueprint could then be drawn up of the cracks, so that reinforcing sheets of FRP could be made to the proper weight and size and applied where needed. To anchor the protruding fragments, EPOJET primer was brushed on first, so that the residual dust particles continually forming on the substrate could be contained (Photo 13). ADESILEX PG1, a thixotropic epoxy adhesive for structural bonding, was then trowelled on (Photo 14). Carmine, Pasquale, Gennaro

PHOTO 13

PHOTO 14



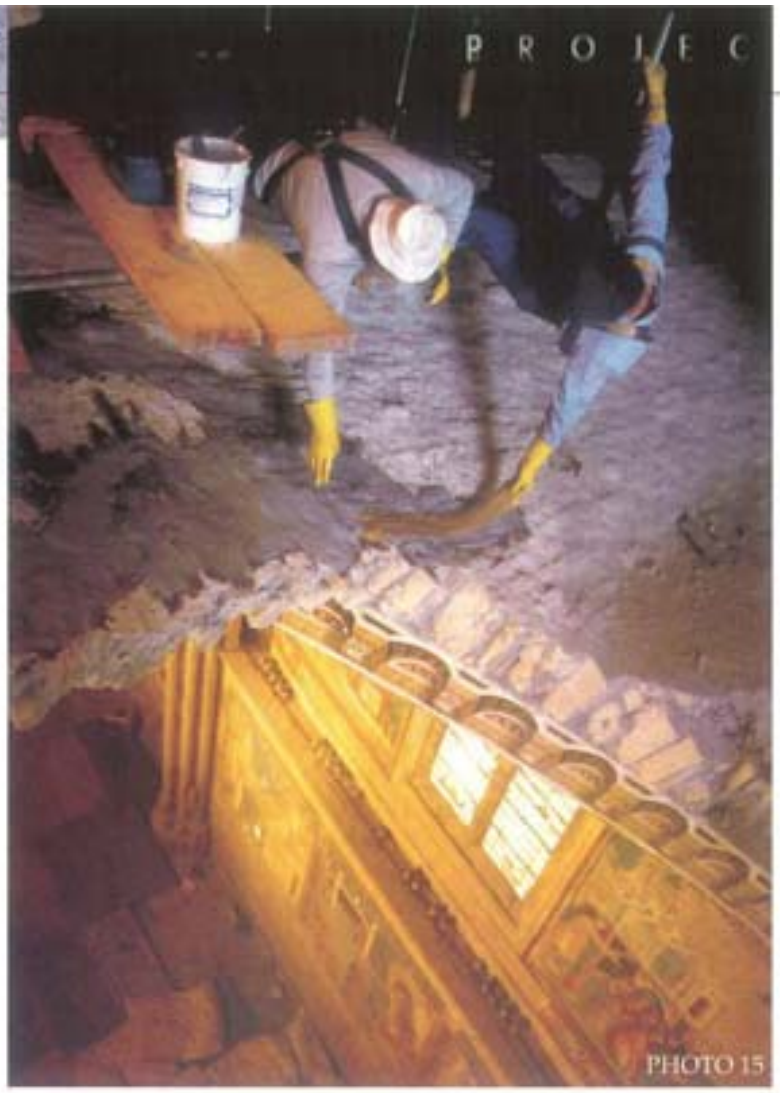


PHOTO 15


PHOTO 16

and Franco, with their backs attached by hooks to the hanging platform, worked with the care and delicacy of fresco painters. Once the surface had been made sufficiently solid and smooth, applying the FRP reinforcing sheets to it required precision and skill. Exerting too much pressure with the tools would have caused debris to fall, particularly bricks that had come almost completely loose on the edge of the surviving vaulting. Excess pressure would also cause the adhesive to penetrate too deeply, damaging the fresco underneath. The repair plan involved first the edges of the collapsed areas and the areas behind these in a preliminary holding operation so that the bonding operation could be performed safely later. Pieces of FRP between 20 and 30 cm wide were then quickly applied over the previously treated areas (Photo 15). The placement and strength of this fabric was carefully calculated to cover the fracture pattern, and the basic weight of each one was determined by specific technical considerations. (Photo 16).

Repairing the vaulting

The third and last stage of repair work on the Franciscan church involved the entire system of vaulting which had almost completely detached from the side walls during the earthquakes, with cracks up to 8/10 cm wide along the whole length of the Basilica.
In the opinion of Giorgio Croci and Paolo Rocchi, the two professors who were appointed project managers by the Committee for the Restoration of the Basilica Complex of St. Francis in Assisi, the collapse of the vaulting was caused for the most part by the enormous amount of filler material that had accumulated over the centuries at the juncture of the springers and reins of the vaults, i.e. along the side walls. During the earthquake this loose material exerted very high pressure alternately on either side of the vaulting, causing it to bend tremendously, while making the vaulting and the ribs which support it lose their curvature. To prevent the collapse of the entire structure this accumulated material, weighing 1000 tons, had to be removed. Then the cracks along the entire length of the vaulting had to be repaired, using a binder that had high mechanical strength, yet was similar to mortars used at the time the Basilica was built.
Repair of the "period" lime mortar that had been pulverized was done with MAPE-ANTIQUE MC, a light colored dehumidifying mortar for period buildings that possesses the same physio-mechanical characteristics of porosity and vapor permeability as antique mortars based on lime and pozzolan (Photos 17 and 18). Based on special hydraulic binders and natural sand, MAPE-

PHOTO 17

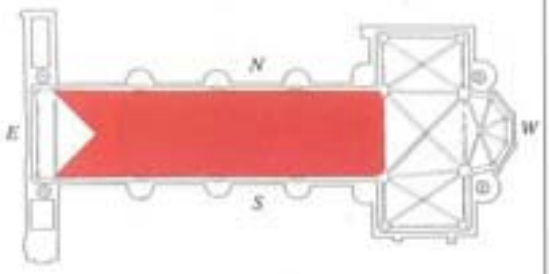


PHOTO 18

PHOTO 19

PHOTO 20

PHOTO 21

PHOTO 22

ANTIQUE MC is especially resistant to sulphate salts, which are one of the major causes of deterioration in period buildings. Moreover, the formulation's low salt content makes this mortar resistant to chemical and physical agents, preventing damage to the frescoes underneath. Once the whole vaulting system was stabilized, a decision was made to suspend the most critical areas of the vaults from the masonry arches that support the roof by using a series of tension wires. These were designed with two springs (Photo 19) to provide constant tension regardless of thermal effects or other deformations. They were anchored to the top of the masonry arches (that date from the 15th century) and to the base of special "connectors" made on site. The same technique was used to make these connectors as was used on the groin: after applying an epoxy system of EPOJET resin (Photo 20) and ADESILEX PG1 (Photo 21) sheets of FRP were made and placed in position by specialists (Photo 22), then cut to the measurements

PHOTO 23

PHOTO 24

of the section, and molded perfectly to the texture of the surface. Dozens of these connectors of different shapes and sizes (Photo 23) tied the critical areas of the vaulting to the arches and to the roof itself (which had been recovered in the 15th century with tiles) (Photo 24, 25). Professors Croci and Rocchi

PHOTO 25

maintain that even if the vaulting should break free of the side walls during another earthquake, it would remain suspended from the arches by this system of wires.
A Mapei solution for preserving tradition! ❑

Our thanks to Paolo Lombardi and Renato Cucchiarini for their invaluable collaboration.

Our thanks for permission to print Photos 2, 8, and 9, from "The Vaulting of the Upper Basilica of St. Francis in Assisi" by Giorgio Bonsanti, published by Franco Cosimo Panini.

The technical sheets of the products mentioned in this article are contained in Mapei binder N. 3 "Building line".

TECHNICAL DATA

THE BASILICA AND MONASTERY OF ST. FRANCIS IN ASSISI

Year of construction: first half of the XIII century
Restored after the earthquakes of September-October 1997

Project Manager:
Dott. Antonio Paolucci, Artistic and historic adviser (coordinator)
Dott. Arch. Costantino Cetroni, BB.AA.AA.AA.SS. Superintendent of Umbria (interior design)
Prof. Ing. Giorgio Croci (exterior design)
Prof. Arch. Paolo Rocchi (exterior design)
Central Restoration Institute (fresco consultant)

Job-site Supervisor: Dott. Arch. Costantino Centroni
Collaborator: Geom. Raoul Paggetta

Project associates:
Dott. Eng. Giuseppe Carluccio
Dott. Eng. Mario Biritognolo
Dott. Arch. Aymen Herzalla
Dott. Arch. Rosalba Lombardo
Dott. Eng. Michele Tataseo
Dott. Arch. Anna Rita Turlò
Dott. Eng. Alberto Viskovic

Restoration of the groin:
S.A.C.E.N., Naples
Consulting Engineers for S.A.C.E.N.:
Eng. Alberto Balsamo and Umberto Battista

Restoration of the vaulting:
Lunghi, S. Maria degli Angeli (PG)

Technical Supervisor for Lunghi:
Eng. Luca Lunghi

Mapei products used:
PRIMER EP
EPOJET
ADESILEX PG1
MAPE-ANTIQUE MC

The Mapei products mentioned are part of Mapei's European product lines