

GLOBAL BLUEPRINTS FOR CHANGE

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The Global Blueprints for Change contain guidance for working together to improve the capability to identify indicators of physical, social, enterprise, and environmental vulnerabilities throughout the world and to select and implement realistic solutions to reduce them towards acceptable levels.

**Theme A: LIVING WITH NATURAL AND TECHNOLOGICAL HAZARDS
Topic A.11: Reducing Risk to Cultural Heritage**

**" Restoration and Preservation of Medieval Churches:
Responding to Natural Disasters "**

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Restoration and Preservation of Medieval Churches: Responding to Natural Disasters

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Abstract: This Blueprint for Change will provide guidance to communities throughout the world that are seeking cost-effective ways to preserve and protect historical buildings, antiquities, monuments, and other national treasures from the potential impacts of natural and environmental disasters.

Background

American engineers involved in preservation or restoration of historic structures are accustomed to thinking in terms of dealing with problems resulting from the physical deterioration of or physical damage to structures constructed in the 19th century or, in rare cases, the 18th century. In many cases similar building materials are still at hand and construction details and even construction practices have often only changed minimally from those employed in the original construction of the structure. Furthermore, rarely do these engineers have to take into account during their preservation and restoration efforts the problems attendant to preservation or restoration of non-structural elements such as painting, sculpture and decorative glass that are inseparable from the structure and are, in some cases, more precious than the structure itself. Consequently, they can usually focus most, if not all, of their attention on the structural problems inherent in preservation and restoration — problems well within the purview of the engineer's education and experience.

European engineers engaged in similar work are not so fortunate. They often work with structures 500 years old or older. Consequently, building materials and construction details cannot be duplicated or can only be duplicated at great expense. Also, they are frequently required to coordinate their approach to preservation and restoration work, as well as the accomplishment of the work itself, with art historians and other experts who may impose restrictions necessary to protect and preserve decorative elements of inestimable value. Finally, while American engineers who wrestle with restoration and preservation problems often have their work scrutinized by local special interest groups, European engineers engaged in this work often experience the feeling that “the whole world is watching.”

Because of the large number of historic structures in Europe, and because these structures are geographically distributed over a large region, they have been exposed to natural disasters of almost every conceivable variety. Over the hundreds of years of exposure, a great deal has been learned about preservation and restoration

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practices. Some of what has been learned has been lost and some has been made obsolete by the availability of new materials and new equipment, but a substantial amount of information on European efforts in preservation and restoration over the last several decades is well documented and available.

Some of the most complex and most interesting preservation and restoration projects have been carried out in and around great medieval churches. The large number of ancient church structures and their geographic ubiquity subject them to a relatively large number of natural disasters. The emotional attachment to these structures as places of worship and as cornerstones of religious and cultural history, as well as their economic importance as sites for tourism, have made them popular candidates for preservation and restoration efforts. Four examples of restoration and preservation efforts at medieval churches damaged by natural disasters in the last several decades are cited herein to illustrate the problems encountered and solutions employed.

Santa Maria Novella, Santa Croce and Santa Maria del Fiore in Florence, Italy

During the night of November 3 and in the morning of November 4, 1966, following more than a week of almost continuous rain in Tuscany, heavy rains pounded the city of Florence. The Arno River which runs through the city, already swollen with the runoff from rains of the previous week, left its banks and inundated the center of the historic city, burying it under as much as ten feet of water and depositing more than 500,000 tons of mud. Although the Arno River had produced spectacular floods several times in the preceding 150 years, little had been done to protect museums, libraries, churches and government buildings containing treasures of medieval and renaissance art from the devastating floodwaters. By the time it became obvious that the magnitude of this flood would be beyond anything recorded in Florence, there was insufficient time to prepare either the structures or the treasures they contained for the onslaught of the flood. As the floodwaters rose during the daylight hours of November 4, and the magnitude of the impending disaster became apparent, a few of the most valuable books and art treasures were moved to spaces above the reach of the floodwaters, but in most cases there was nothing that could be done to reduce the scope of the disaster.

More than a dozen of the oldest and most important church structures in Florence were inundated by “the waters of November.” Santa Croce, called by some “the Westminster Abbey of Italy” because it contains tombs and monuments to Italian luminaries such as Michelangelo, Machiavelli and Rossini as well as frescos by Giotto and Gaddi and a painted crucifix by Cimabue, is only a few hundred feet from the banks of the Arno. At the peak of the flood, water stood in the church to a depth of seven feet. Similar situations existed at Santa Maria Novella and the great cathedral, Santa Maria del Fiore.

Despite their age, these and other churches in Florence were not seriously threatened with structural failure. Although thousands of students, art historians, and restoration experts from all over the world descended on Florence to assist in the recovery efforts in the several years following the flood, their efforts, for the most part, were devoted to cleaning and restoring the books and works of art that had

suffered the greatest damage. Most of the work on the church structures involved cleaning the interior and exterior walls to remove the stains left by mud, fuel oil, and other water-borne contaminants. A problem that surfaced months after the original cleanup effort, when restoration work on frescoes in Santa Croce was already well underway, was the occurrence of unanticipated moisture in the walls behind the frescoes due to capillary action in the porous stone walls.

York Minster in York, England

On the night of July 9, 1984, lightning struck York Minster, the great cathedral in York, England. In the ensuing fire, the timber roof of the south transept, which had been restored in 1979, was completely destroyed, and the 22-foot-diameter, 16th century rose window was shattered into more than 40,000 fragments. Fires in 1829 and in 1840 had caused substantial damage to other parts of the Minster, but the south transept had been spared. Restoration work on the south transept, which was ultimately to require the expenditure of almost \$4,000,000, commenced immediately.

A temporary plastic roof was installed to provide protection from the elements, and tons of debris were removed from the floor below. Dirt and soot were removed from the walls and glass. Using a fifty-year old saw, the only piece of equipment able to handle such long pieces, fifty forty-foot oak beams were hewn from giant oak trees donated by landowners throughout the nation. The beams were kiln-dried for seven weeks before being installed to provide the ribs for the roof structure. Sixty-two of the sixty-eight bosses which existed at the junctions of major ribs were also destroyed in the fire and had to be reconstructed.

The seventy-three panels making up the rose window had consisted of more than 7,000 individual pieces of glass. The panels had been re-leaded and the composition of the window had been documented using modern methods in 1969-70 by the York Glaziers Trust as an element of an ongoing preservation program. Consequently, not a single fragment of glass was lost, despite the fragmentation caused by the severe heat. Over the next four years the window was painstakingly cleaned and reassembled using a special adhesive developed by the 3M Corporation. The adhesive has the same index of refraction as the glass, so that seams in the reconstructed pieces are as unobtrusive as possible. Each piece of reconstructed glass was then sandwiched between two pieces of clear glass to strengthen and protect the window.

Four years after the fire the south transept was reopened. In the floor of the transept is an inscription that reads as follows:

*Remember with gratitude
all who helped restore this
transept after the fire of 9th July,
1984. It was re-opened in the
presence of Her Majesty the Queen
on 4th November, 1988.*

All around the top of the new entrance to the south transept are inscribed the names of the men and women involved in the restoration.

Basilica of St. Francis in Assisi, Italy

On Thursday, September 4, 1997, an earthquake measuring about 6.0 on the Richter scale shook the Basilica of St. Francis in Assisi, Italy. Construction of the basilica began soon after the death of St. Francis in 1226 and the church was completed in 1236. Frescoes by Cimabue and Giotto and several other Italian artists were commissioned to decorate the vaults and walls of the great church during the fifty-year period following the completion of the church structure. The earthquake caused a very limited amount of damage — mostly a few chips fallen from frescoes already judged to be in poor condition.

In the early morning hours of Friday, September 26, 1997, tremors again shook the 700-year-old church. This time the damage was more substantial. Chips of frescoes had fallen from the ceiling and the walls and ominous cracks appeared in the ceiling vaults. A photographer who had been commissioned to photograph the frescoes for a forthcoming publication found a 15-pound chunk of stone on the floor of the basilica and discovered that it had fallen from a column separating two panels of a stained glass window. By 11:00 a.m. more than 25 persons were inside the basilica surveying the damage from the latest tremor and trying to pick up the chips of plaster for use in planned restorations. At 11:42 a thunderous rumble was heard and three sections of the masonry vaulting collapsed, trapping two Franciscan monks and two restoration experts who were examining the damage from the earthquake earlier that morning. For the next ten days the basilica was shaken regularly by aftershocks which increased the damage.

Restoration of the basilica has been carried out over the ensuing years. The brick arches and masonry vaulting that collapsed have been reconstructed and strengthened through the use of wire bundles that attached the roof to the walls. The bundles consist of 80 nickel-titanium “shape memory” alloy wires, each 1 millimeter in diameter and 70 centimeters long. The wires can be bent or stretched, but they recover their shapes automatically. They will allow the walls and roof to move independently during a tremor and then return to their original position. Restoration of the frescoes is a more difficult problem. Thousands of tiny fragments were crushed or lost in the rubble, but some larger fragments have been found. Restoration work on these art treasures will continue for many years.

The basilica reopened to visitors early this year. The cost of the restoration work thus far has been more than \$60,000,000. Structural engineers estimate that the building will now be able to withstand earthquakes one-and-a-half times as strong as the one that brought the ceiling down four years ago.

St. Mark's Basilica in Venice, Italy

One of the most famous public buildings in Italy is St. Mark's Basilica in Venice. St. Mark's Square, the *Piazza San Marco*, is one of the most photographed locations on earth. But St. Mark's Square and Basilica are threatened by a phenomenon the Italians call *acqua alta*, “high water.” For hundreds of years Venice, constructed on a series of islands in a sheltered lagoon, has been slowly subsiding.

Subsidence in the vicinity of St. Mark's is now estimated to occur at the rate of about an eighth-of-an-inch a year. The problems caused by subsidence are compounded by increasing sea levels. Flooding in St. Mark's Square which occurred only seven times in ten years during the 1920s now occurs as often as 20 times a year. Most of these inundations only produce inconveniences for citizens of Venice who live and work around the basilica and for tourists who visit it, but increasingly often tidal levels are threatening the basilica itself. Protection of the art treasures inside the basilica is a major concern, but some people question the effects of repeated flooding on the structural integrity of the basilica.

For more than 30 years engineers from around the world have worked to develop solutions to the flooding problem. Solutions proposed range from raising the banks of the lagoon to installation of tidal barriers at the entrances to the lagoon. Cost estimates for the proposed solutions range from \$3 billion for the tidal barrier schemes to \$23 million for a scheme which involves the installation of an impermeable membrane between the *piazza* and the drainage channels beneath it (which allow sea water to back up into the *piazza* when the tide level exceeds the outlet elevation for the drainage system) and raising the level of the lagoon bank in the vicinity of St. Mark's by about eight inches. Both types of solutions have major problems associated with them. The cost of the tidal barrier scheme is, of course, a major problem, but there are also potential environmental problems due to adverse effects on the circulation of water in the lagoon. The lower-cost solutions are plagued by the fact that the drainage system under the *piazza*, installed in the 18th century, is needed to carry away surface water in the *piazza* area. Stopping the incursion of sea water due to high tides also inhibits the drainage of surface water. How this problem of flooding will ultimately be solved remains to be seen.

Conclusion

The great medieval churches of Europe have provided a testing and proving ground for engineers engaged in the work of preserving and restoring historic churches. The complexity of the problems encountered in working with these great structures challenges the ability of the engineer as dramatically as the work on the art treasures inside them challenges the ingenuity of artists and art historians. In the United States where preservation and restoration work is, relatively speaking in its infancy, we have much to contribute from our knowledge of new materials, but we also have much to learn from those who have been engaged in that work for many decades

Additional Material

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