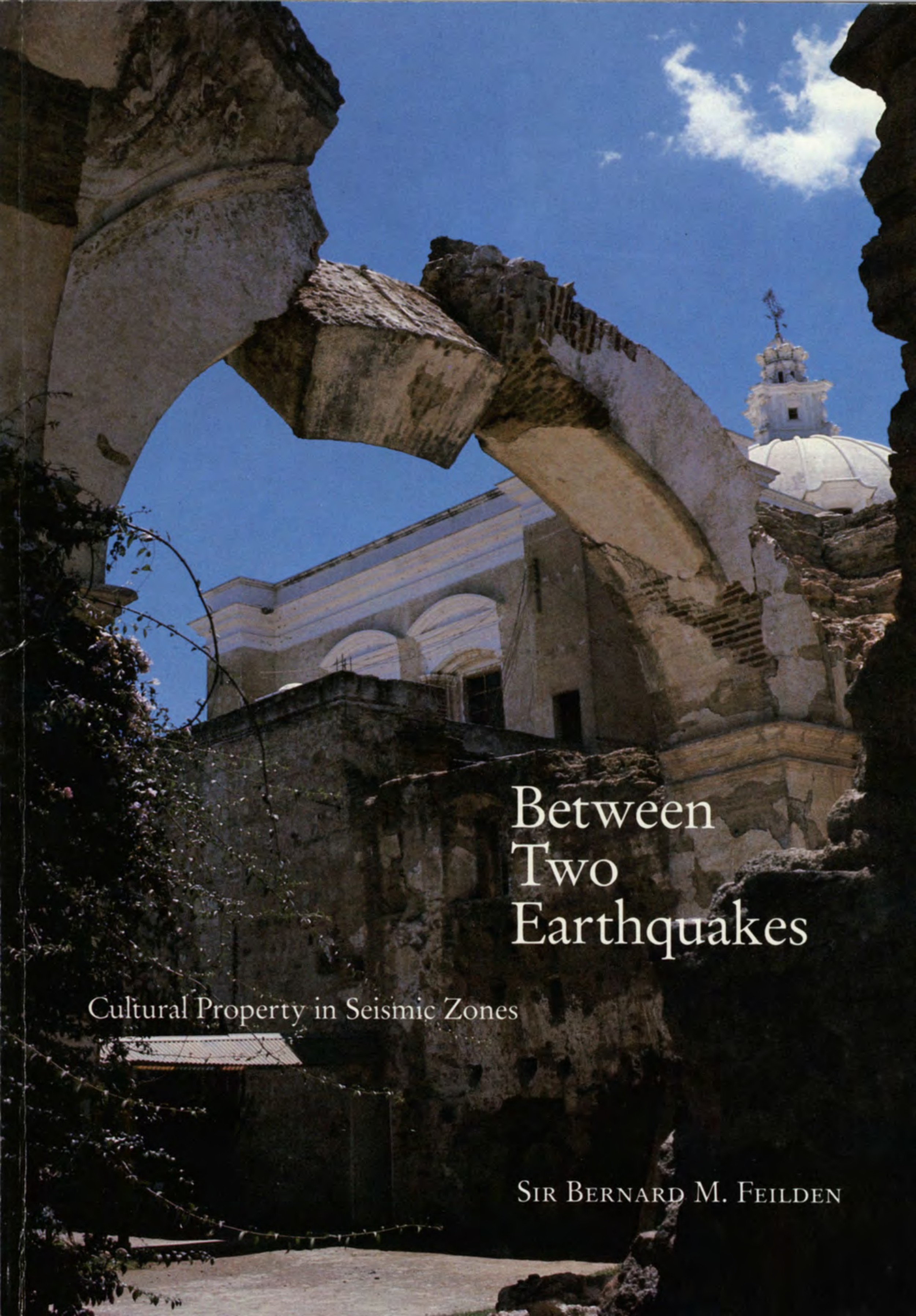

Between Two Earthquakes

Cultural Property in Seismic Zones

Sir Bernard M. Feilden

Between Two Earthquakes:
Cultural Property in Seismic Zones

A joint publication of
ICCROM and the
Getty Conservation Institute

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Cover: Arch of San Francisco after the 1976 earthquake, Antigua, Guatemala.

Between Two Earthquakes

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SIR BERNARD M. FEILDEN

Bernard Feilden's architectural firm has won more than fifteen prestigious awards, six for which he was personally responsible. He is the recipient of the Europa Nostra Silver Medal for his Chesterfield conservation scheme and the Aga Khan Award for the restoration of the painted dome of the Al Agzah mosque. In 1983, he became Director Emeritus of ICCROM, after serving as Director from 1977 to 1981. He now serves as President of the United Kingdom National Committee of ICOMOS and as a member of the Advisory Committee for the Central Council for the Care of Churches and Cathedrals. His techniques for meticulous inspection saved the spire of Norwich Cathedral and the fabric of York Minster, which is detailed in his book, *The Wonder of York Minster*. His other books include *The Conservation of Historic Buildings* and *An Introduction to Conservation of Cultural Property*. His many appointments include Honorary Doctor of the University of York, Fellow of the Society of Antiquaries, Fellow of the Royal Society of Arts, Fellow of the Royal Institute of British Architects, and, most recently, Honorary Fellow of the American Institute of Architects. In recognition of his achievements he was knighted by Queen Elizabeth in 1985.

ICCROM

The International Centre for the Study of the Preservation and the Restoration of Cultural Property (ICCROM) is an intergovernmental organization created by UNESCO in 1959. It now has seventy-five Member States and sixty-four Associate Members (nonprofit conservation institutions) throughout the world. Its headquarters are in Rome. ICCROM's statutory functions are as follows: to collect and disseminate documentation on scientific problems of conservation; to promote research in this field; to provide advice on technical questions; and to assist in training technicians and raising the standard of restoration work. To carry out this task, ICCROM has developed a specialized library, a regular training program and experimental courses, a publications section, a technical assistance program, and research projects. ICCROM also organizes symposia on various conservation topics and works closely with other organizations committed to the conservation of cultural property.

THE GETTY CONSERVATION INSTITUTE

The Getty Conservation Institute (GCI), an operating program of the J. Paul Getty Trust, was created in 1982 to enhance the quality of conservation practice in the world today. Based on the belief that the best approach to conservation is interdisciplinary, the Institute brings together the knowledge of conservators, scientists, and art historians. Through a combination of in-house activities and collaborative ventures with other organizations, the Institute plays a catalytic role that contributes substantially to the conservation of our cultural heritage. The Institute aims to further scientific research, to increase conservation training opportunities, and to strengthen communication among specialists. The other operating programs of the J. Paul Getty Trust are the J. Paul Getty Museum; the Getty Center for the History of Art and the Humanities; the Getty Art History Information Program; the Getty Center for Education in the Arts; the Museum Management Institute; and the Program for Art on Film, a joint venture with the Metropolitan Museum of Art.

Foreword

A crucial part of conserving the cultural heritage is the protection of significant property that is located in seismic zones.

This handbook has been produced through ICCROM and the Getty Conservation Institute (GCI) to provide information on conserving historic buildings, monuments, and archaeological sites in earthquake-prone areas. It is recognized that such a handbook can only be an introduction to this vast and complex subject, and cannot address in detail the engineering aspects of earthquakes, nor detailed actions needed during a disaster.

Many people have contributed directly or indirectly to this handbook, including David Dowrick, Pierre Pichard, and Barclay G. Jones. Other contributions grew out of the 1979 ICOMOS meeting in Antigua, Guatemala; the 1982 conference organized by the Architectural Research Center Consortium, National Academy of Sciences, United States; the 1985 United States/Yugoslav seminar at Petrovac and Budva; and the 1985 ICCROM/IZIIS seminar at Skopje, Yugoslavia. Special appreciation is extended to Cevat Erder, Director, ICCROM, and to the Getty Conservation Institute, under the direction of Luis Monreal, which has made this publication possible.

This handbook is published with the assistance of the Disaster Planning Steering Committee of the GCI. Helpful comments and suggestions have been made by Jukka Jokilehto and Jef Malliet of ICCROM, Norbert Baer of New York University's Conservation Center of the Institute of Fine Arts, Anshel J. Schiff of Stanford University's Engineering Department, Phillip H. Babcock of the Smithsonian Institution, Philip Ward of the Canadian Conservation Institute, and Kathleen Tierney of the University of Southern California's Institute of Safety and Systems Management.

Sir Bernard M. Feilden C.B.E.

Introduction

Earthquakes--the shifting of the earth's crust--can result in devastating destruction. While there is a growing body of knowledge about the nature of earthquakes, we cannot predict with confidence either their precise time of arrival or their intensity. We can predict only that they will eventually happen.

Even with our present level of technology, we can do nothing to reduce either the frequency or the intensity of earthquakes. The only thing we can do is take precautions to mitigate potential devastation. Beyond the obvious need to protect human life, we must also take the responsibility of protecting historic buildings and monuments. Already we have suffered major losses of important structures.

Earthquakes are different from other disasters in their capacity to destroy almost instantaneously without warning, causing extensive, often irreparable damage to cultural property. Preparing for and responding to earthquakes involves local, provincial, and national (or federal) organizations.

Organizations responsible for the care of cultural property are referred to as the Administration in this handbook, and their directors, as Administrators. It is these Administrations that can--indeed, that *must*--take major steps to organize disaster preparedness in order to save lives and the irreplaceable cultural heritage.

Earthquake preparedness must incorporate planning for contingencies common to most other types of disasters--especially fire, flood, and looting. By planning ahead, vital time can be saved after the disaster has struck. Fortunately, the conservation of cultural property utilizes different skills, techniques, and materials from those required to save lives and reconstruct modern buildings. As a result, conserving our cultural heritage does not necessarily compete with other recovery operations for scarce resources in the post-disaster situation.

Improvement of the seismic resistance of historic buildings should be integrated into a regular maintenance program, based upon periodic inspections

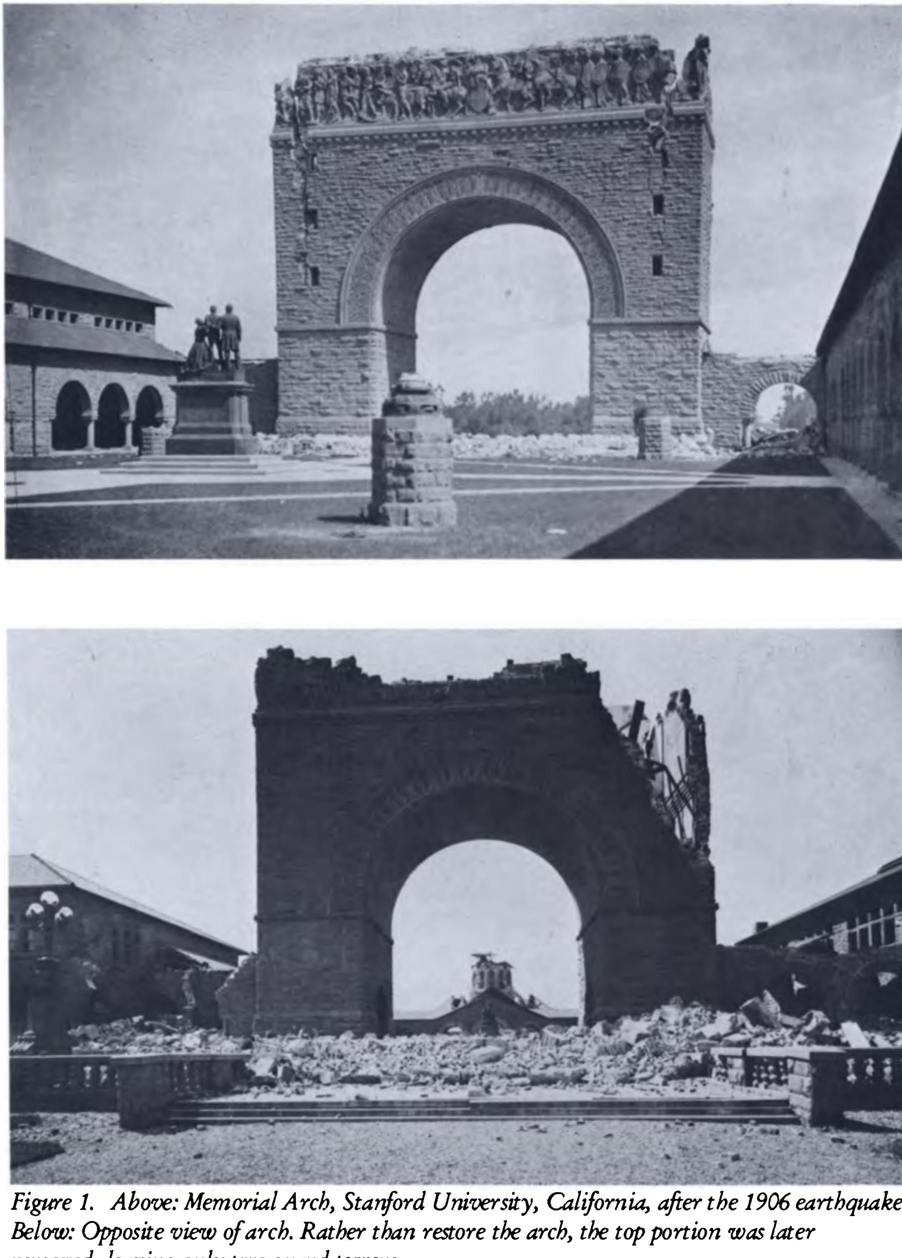


Figure 1. Above: Memorial Arch, Stanford University, California, after the 1906 earthquake. Below: Opposite view of arch. Rather than restore the arch, the top portion was later removed, leaving only two guard towers.

by specially trained architects and engineers. Administrators in seismic areas should ensure that these inspections are carried out and that a full inventory with detailed documentation is prepared before the next earthquake.

When natural disasters--hurricanes, typhoons, tornadoes, floods, blizzards, avalanches, and so on--strike, the infrastructure of a community is often thrown out of action. After initial help arrives, complete restoration may take several years.

Thus, this handbook addresses three areas of concern for the Administrator: what to do before the earthquake strikes, what to do immediately after, and what long-term actions remain to be taken.

The application of the advice given in this handbook must incorporate the difficulties posed by different systems of government, different legal and administrative practices, different planning procedures, different patterns of ownership, and different cultural attitudes. But none of these differences need deter the Administrator from applying the principles recommended for saving both lives and property. Many of these properties will be historic buildings, even if only humble vernacular cottages. Many will contain valuable objects of cultural heritage. Preventive action is the duty and responsibility of these Administrators whose foresight should be recognized and honored.

Disaster preparedness has to combat the natural inclination of the population to say "It won't happen here--or, not in my time." However, the only responsible policy is to work consistently and effectively to plan for the eventuality of an earthquake.

Furthermore, each earthquake must become another significant chapter in our growing body of knowledge. Repair and reconstruction after the last earthquake have to be studied. Lessons must be learned continually and we must always be aware that we live *Between Two Earthquakes*.

Figure 2. Cathedral after the May 6, 1976 earthquake; Venzone, Friuli.

CHAPTER I

Cultural Heritage and Earthquakes

Nature of earthquakes

The surface of the earth consists of about twenty independent tectonic plates floating on a softer inner layer. These plates are in continuous motion relative to each other because of currents in the internal liquid core of the earth. Thus, elastic energy accumulates along the edges of the plates, and it is eventually released with a sudden movement, which causes brief, strong vibrations in the ground: an earthquake.

The place in the earth's crust where this energy release occurs is the focus, or hypocenter, of the earthquake. The corresponding place on the surface is the epicenter. The vibrations propagate very quickly in all directions, but become gradually weaker with distance.

Very often a major earthquake is preceded by some foreshocks and is nearly always followed by aftershocks, some of which can be of comparable strength. The interpretation of foreshocks is difficult and thus they are seldom useful in predicting a major earthquake. Aftershocks can be very dangerous, as they will act upon already damaged structures.

Magnitude and intensity

The magnitude of an earthquake is expressed in degrees on the Richter scale. It indicates the absolute strength or energy release of the earthquake and is calculated on the basis of recordings of the earthquake by accelerometers or seismographs in different locations.

While magnitude characterizes the earthquake itself, intensity indicates the effects of the earthquake in a determined place. Intensity is most often expressed in degrees (I to XII) on the Modified Mercalli Scale, which classifies the observable damage to buildings and installations caused by the shaking ground (Appendix 5). Damage caused by an earthquake of a given magnitude and the intensity with which the earthquake is felt in a determined place depend on many things: the distance from the epicenter, the main direction, frequency, content, and type of the seismic waves, the local ground conditions, the condition of the buildings affected (i.e., whether they have been well maintained and the quality of workmanship on previous repairs), their form and design, etc.

Maximum ground acceleration is also often used to indicate intensity. It is only one of the important factors determining intensity, but it is a directly measurable value that can be used easily in calculations. It is expressed as a fraction of g, the gravity acceleration.

Figure 3. Cathedral with cracking above arches caused by February 4, 1976, earthquake; Tecpan, Guatemala.

It is not surprising that the unfavorable ground conditions of the 1976 Friuli, Italy earthquake (6.4 Richter) produced as devastating a result (Modified Mercalli IX and X) as the 1976 Guatemala earthquake with a 7.6 Richter, one of the most severe ever recorded, with forty times the energy input of Friuli. In Friuli, the second major shock followed a whole series of minor tremors and caused great havoc to buildings already seriously weakened.

Another significant example is the 1985 Mexico earthquake, with a magnitude of 8.1 and an epicenter in the Pacific Ocean. In Zihuatanejo, on the coast, less than 100 kilometers from the epicenter, the earthquake registered an intensity of VII on the Modified Mercalli Scale, but an intensity of IX in some parts of Mexico City, about 400 kilometers from the epicenter. This was due partly to a focalizing effect in the wave propagation and partly to the geological structure of the valley of Mexico City. Due to local differences in ground conditions, the intensity in Mexico City varied between VI and IX.

The secondary effects of earthquakes, such as landslips, road fractures, bridge failures, floods, and ground movements with changes of underground water levels and flow, can also be devastating. Their first effect is to disrupt communications and make rescue difficult. In addition, an earthquake site is generally held in a pall of dust.

Each state or federal government should appoint a disaster relief coordinator responsible for all cultural property, whose duties might include coordinating the work of conservation volunteers. A brief summary of the administrative and technical actions that may be needed before, during, and after a seismic disaster is given below.

Before an earthquake

Administrative

- Make full inventories of all cultural resources, supported by photographs and photogrammetric records of important historic buildings, sculptures, and artistic decoration. Prepare seismic survey forms and outline drawings of all important buildings. Keep duplicate records preferably in a nonseismic zone or in an earthquake- and fire-resistant building.
- Educate the public on the importance of historic buildings, maintenance, and seismic upgrading of vernacular buildings. Publish guidelines for local builders on the correct techniques for maintaining

and upgrading buildings, and preserve skills and materials needed for maintenance and repair of historic buildings.

- Install a national or regional emergency group for the protection of cultural property.
- Train architects and engineers in seismic resistant design and inspection for historic buildings.
- Insure movable objects when feasible. Insurance, however, should be considered the last line of defense. Efforts should be directed primarily at eliminating or at least mitigating risks of loss, particularly since almost all cultural properties and artifacts are irreplaceable.

Technical

- Commission geological studies indicating underlying site properties and geologic structure.
- Initiate seismic studies, including historic records, to evaluate return periods of earthquakes with various intensities.
- Develop vulnerability studies for earthquakes of different intensities. Such studies should relate to the artistic and historical value of the buildings, their furnishings, and their contents.
- Compile town and country plans relating developments to various grades of seismic damage.
- Assess risk to the infrastructure of roads, drainage, water, gas, electricity, telephones, and other installations. Initiate antiseismic design for these "lifelines."
- Prepare seismic safety plans for historic buildings. Strengthen buildings by stages when this becomes economical.

When disaster strikes

- Fight fires and prevent looting of works of art. Prevent water damage from rupture of water supply pipes or firefighting.
- Protect as much cultural property as possible. Label and transport all movable cultural property to previously designated warehouses, fumigate, and give first aid.
- Obtain the cooperation of local civil and military authorities as soon as possible.

- Organize a quick inspection of damage and coordinate the work of conservators, architects, and engineers. Grade damage to buildings.
- Set up multidisciplinary conservation teams and allocate materials and labor to repairs, giving priority to immediate protection against the weather.
- Seek international aid through disaster relief agencies, requesting special equipment as needed.

After the disaster: long term

- Organize an in-depth assessment of damage with estimates of costs of restoration (see standard forms in Appendix 7).
- Establish priorities for the program of restoration and repair.
- Execute structural repairs using teams of architects trained in preservation, as well as engineers, historians, and archaeologists.
- Set up multidisciplinary teams to propose projects for repair and reconstruction of damaged buildings, making certain that the engineers' work is integrated into the architectural/historical methodology in accordance with the resolutions of the 1985 Skopje Symposium (Appendix 9).
- Evaluate alternative schemes balancing risk and vulnerability against degree of intervention and loss of cultural values.
- Present plans for public approval and support. Execute structural repairs.

Figure 4. "But I still have my son and my cat." Gemona, Italy, after the 1976 earthquake.

CHAPTER II

Before Disaster

Predisaster measures may take a considerable amount of time and effort, but the time that will be saved after the disaster is extremely valuable. The cost of earthquake damage can easily double if repairs are delayed two to three years. Without adequate planning and preparation, whole buildings can be lost.

Documentation

Recording and documentation are particularly vital in earthquake-prone zones and should be given high priority. Existing documentation must be collected and protected. Legislation or other governmental action may be necessary to establish the inventory of cultural property in some countries. Criteria for listing must be established, the simplest being age--say, one hundred years--with the recognition that some recent structures are also important.

After an earthquake, a precise knowledge of every historic building and its contents is one of the most crucial factors in making an accurate assessment of the damage and conservation work required. Moreover, detailed documentation showing the form and condition of each building before the earthquake is essential to its eventual repair.

It is necessary to assemble the following documents relating to each historic structure:

1. A detailed architectural description, accurate sketches, graphic records, etc., on a scale suited to the dimensions of the monument (preferably 1:50 unless it is too large, with detailed drawings at 1:20 or 1:10)

2. A detailed file on all previous repairs, maintenance, and conversion work

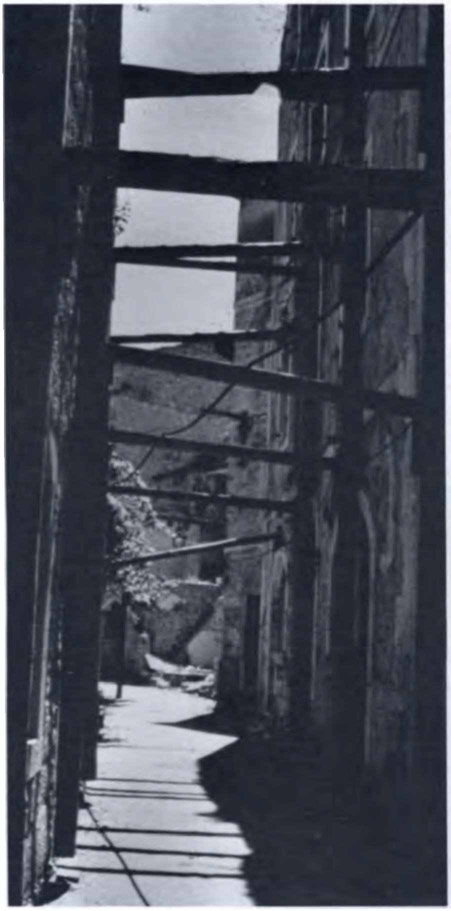


Figure 5. Temporary shoring between two vernacular buildings following 1979 earthquake, Budva, Yugoslavia.

Figure 6. On the other side of the wall, only the shell of the building remains.

3. A comprehensive set of black-and-white and color photographs of archival quality (general views and close-ups of outside and inside)
4. Complete and accurate inventories of the movable property within the structure
5. Up-to-date bibliographic references and documentation on the complete history of the structure

Several copies of these documents, including some on microfilm, should be kept and deposited on the safest possible premises, preferably in nonseismic zones. Original documents (photographic negatives, original drawings, etc.), should be kept in a building constructed according to the highest standards of seismic resistance.

Recording by photogrammetry

Historic buildings in seismic regions may be seriously damaged or destroyed at any moment. Photogrammetric surveys made before the disaster assist immeasurably in the assessment of damage. Systematic photogrammetry campaigns should be organized to cover the structures in all earthquake zones. Photograms can be stored and retrieved at a later stage provided compatible equipment is available. Records can be built up by stages as part of a long-term program of photogrammetry.

Upkeep and retrieval of information

Maintaining records is time consuming, and varying lists of cultural property can cause confusion. A strong case can be made for using a computer database for lists and other information relevant to historic structures.

Documentation may be assembled at national, regional, or local levels. In any case, the Administration should have at each local office plans of the sites for which it is responsible, as well as a set of photographs.

During an emergency, the greatest need is for simple plans of every historic site in order to note damage and calculate equipment and material requirements. These simple and accurate drawings should be on a small scale for ease of handling in the field. (Exceptional cases apart, monument drawings should fit on standard-size paper that can be easily photocopied.)

Movable objects

The contents of historic buildings are often an essential part of their total message. Clearly, priority should be given to the protection of irreplaceable objects. These objects must be cataloged, photographed, and valued. It is difficult to calculate the insurance value of an irreplaceable object. It is important to secure all objects against vibration; special shock-reducing mounts should be developed for statuary, particularly standing figures that have a tendency to break off at the base in an earthquake.

Knowing the risk

Inhabitants of seismic zones must realize they live *Between Two Earthquakes*. Barclay G. Jones (1986a:73,76) observes that, even after Administrators recognize the problem and take steps, their policies and preparations must continually be updated and reevaluated. "Institutions and public bodies must face the problem and establish policies" to protect the cultural heritage.

Once individuals and organizations confront the real possibility of an earthquake--and acknowledge the devastation it can cause--they must take administrative action. Complete safety is unattainable, so the issue is how much safety is feasible to achieve, or conversely how much danger is tolerable. Three concepts are involved in assessing dangers:

HAZARD	the probability that a disastrous event of given intensity will occur in a particular place
VULNERABILITY	the degree of loss that will be sustained by an element from an earthquake of given intensity
RISK	the probable loss, combining the hazards of location and the vulnerability of buildings and their contents. Risk can be removed, transferred, shared, accepted, or accommodated

A major earthquake may affect several administrative zones, provinces, or even countries. It is necessary to make not only a hazard assessment of a country, but also very specific and technical assessments of sites containing valuable cultural property.

Seismicity

An important concept for characterizing seismicity is the return period of earthquakes. The mean-time interval between two earthquakes of a certain intensity at a certain place is called the return period of earthquakes with that intensity at that place. Return periods are of limited use for prediction, especially when the place is subject to earthquakes from various independent foci, but they provide valuable statistical information. The return periods of earthquakes of various intensities enable the risk to be assessed. In the ancient capital of Pagan in Burma, the acceleration rate is estimated at 0.2 *g* with a return period of one hundred years, but in five hundred years, the estimate increases to 0.6 *g*. A large and recent earthquake indicates less probability of reoccurrence; thus, the hazard is lower, but increases with time.

In all estimates of accelerations and return periods, there is a large element of doubt. For safety reasons, the seismologist may overestimate and this may lead to unnecessary interventions in historic buildings. At present, it is thought wiser not to evaluate intensities with return periods greater than one hundred years when designing strengthening measures for historic buildings, as this will avoid excessive interventions that may not last the specified return period. It is better to devise schemes that do not prejudice future interventions and that can be strengthened if desired. Maximum accelerations should be given for specific sites so that alternative courses of action can be studied and compared.

Seismic zones

Seismic zones correspond mainly to the edges of the tectonic plates that support the continents and oceans. Seismic maps are available in every country and are periodically updated, although, as Pierre Pichard (1984:34-35) explains, "These maps are not, as a rule, distributed widely enough and in more cases are unknown, for example, to those responsible for the preservation of monuments." However, these maps are invaluable in establishing a clear picture of the most threatened sites.

It is therefore recommended that national and international organizations responsible for the cultural heritage cooperate with scientific and governmental authorities to develop seismic maps that pinpoint historic monuments, cities and quarters, archaeological sites, and significant museums and libraries. This will provide a clear picture of the most valuable sites and of the priorities to be observed.

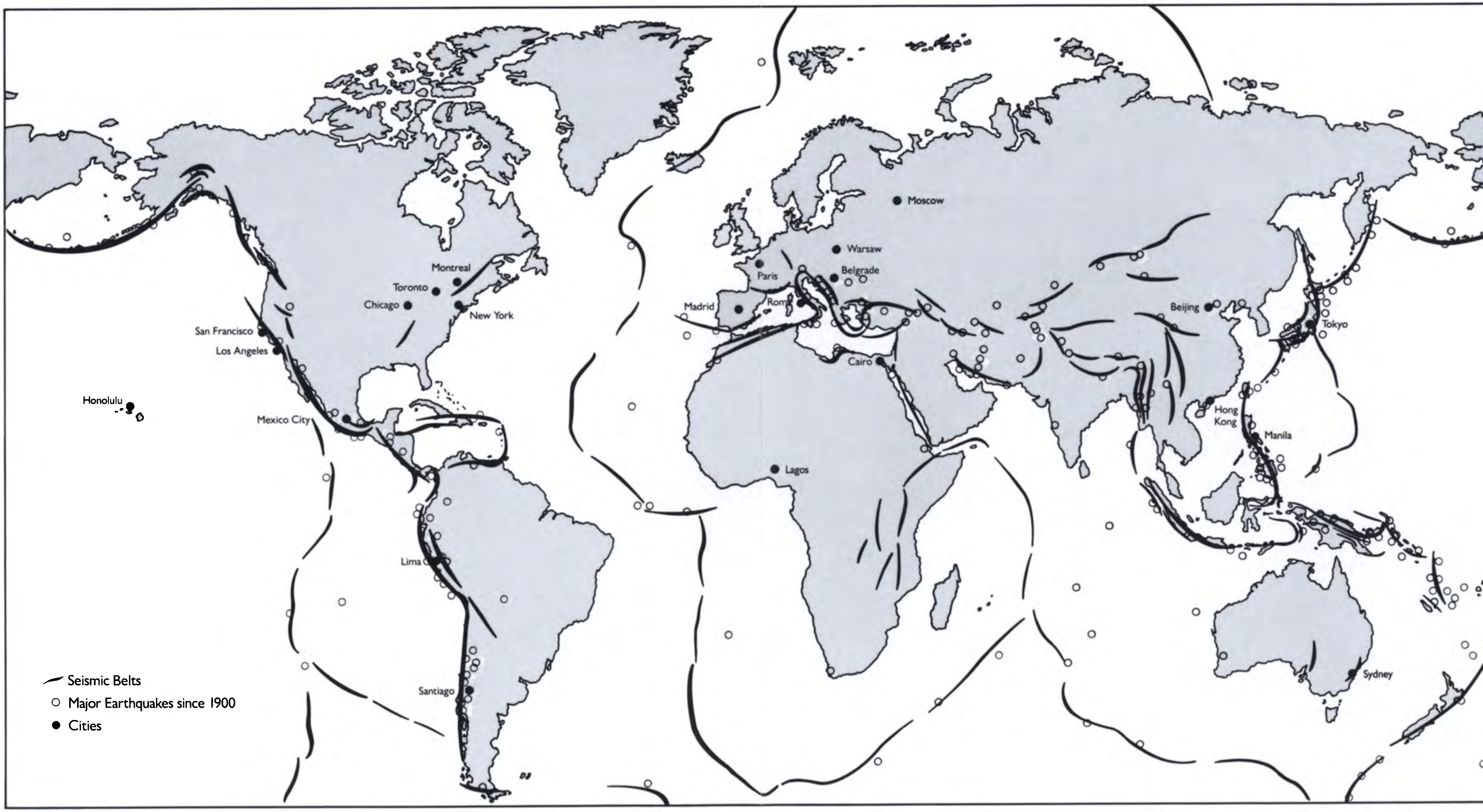
Building vulnerability

The vulnerability of cultural property, both buildings and objects, varies widely. This vulnerability derives from the differing characteristics of each particular earthquake, the soil upon which the structure rests, and the characteristics of the structure itself: foundations, intrinsic faults due to form design, lack of bonding, poor workmanship, and extrinsic faults due to lack of maintenance and decay.

Vulnerability reduction plans must be devised and instituted. Regardless of the type of organization or individual responsible, the kinds of objects involved, or the types of natural hazards that exist, the structure of vulnerability reduction plans is consistent: inventory, recording and documentation, risk assessment, protection, emergency procedures, and restorative processes.

Vulnerability studies should be made for earthquakes of different intensities, and the effects of different degrees of proposed intervention should be assessed. Different types of earthquakes will have different impacts on each individual historic structure, but computer models can help assess potential damage from each. These studies will show the most likely scenario and the range of variations from the median.

Figure 7. The February 4, 1976, earthquake reduces the sachristy to rubble, Patzun, Guatemala.



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Lima
Santiago
Sydney
Seismic Belts
Major Earthquakes since 1900
Cities

Acceptable risk

Most national or state codes for new buildings are determined by the estimated thresholds of tolerable risk. Unfortunately, it is rarely possible to do this for historic buildings, especially the large number of rural vernacular buildings or traditional dwellings in historic centers. Jones (1986b:180) discusses types of policies in more detail.

> A frequent strategy is one that is often described as the easy first approach. Here the easiest steps that can be undertaken within the normal operations of the organization to increase the level of protection and reduce risk are the ones that are embarked upon first. The presumption is that further more difficult measures will be undertaken at subsequent stages. Another frequently observed strategy is to give priority attention to the most important or valuable objects. This requires establishing some criteria for importance or value and inventorying and classifying objects accordingly. This strategy is frequently pursued subconsciously and somewhat automatically. To carry it out systematically requires greater effort. Still another kind of strategy is one which attempts to achieve the greatest degree of protection for a given expenditure of resources. This requires surveying natural hazards, determining vulnerabilities and assessing risks and inventorying collections and classifying them by importance and value. Frequently referred to as a cost effective procedure, such a process may be quite costly in itself.

Town planning

Town planning methodology should be a great help in reconstruction after a natural disaster, but unless the plans are ready beforehand and are regularly updated, the effect can be negative because of the uncertainties, blight, and delays caused by waiting for the plans to be formulated. While the displaced occupants wait for a plan, their damaged houses disintegrate due to rain, wind, and frost.

In planning terms, a disaster is also an opportunity to implement overdue changes and environmental improvements. The problem, however, is that the disaster may change demographic projections and the economic base of the community. Thus, the disaster plan must be flexible to accommodate the effect of various possibilities. This in itself will be useful for the long-term plan, as it will tend to minimize the damage inflicted when the predictable disaster occurs.

Some of the changes that may be wrought by a disaster and influence the possibilities that can be incorporated into a long-term plan have been identified by Jones (1981).

> The interrelationships between people and between people and the environment they inhabit in the impacted region will have changed. Past relationships may no longer exist at all, and new relationships may have been created.
>
> Many of the landscape features may have changed drastically. Earth slides and rock slides may have changed the character of large areas and eliminated many physical elements. Subsidence, fault displacement, the devastation of sea surges and tsunami may have substantially altered the landscape and destroyed many of the modifications that had been made by the population to make it productive and useful for their purposes.

A disaster also presents opportunities to correct defects in town planning. At the town planning level, it may be the policy to upgrade dwellings or even to change uses. Jones (1981) lists three ways in which planning might assist reconstruction and recovery: (1) It can increase the efficiency and speed of reconstruction; (2) minimize the effects on the local socioeconomic system; and (3) actually contribute to the development of the region.

Jones also recognizes the negative effects town planning can have if it causes uncertainties and delays in the reconstruction process.

> Carrying out reconstruction with the primary purpose of promoting development may delay the recovery process inordinantly and reduce its efficiency extensively. It also may result in a new system which is even more vulnerable certainly in terms of higher levels of economic loss than the previous community. Likewise pursuing any two of the three objectives could seriously jeopardize the achievement of the third.
>
> Everything that is done in the reconstruction process must conform in a very profound way with the nature of the existing system in the region and the trends of its evolution. Otherwise the activities are likely to be counterproductive and lead to less than optimal results.

Ownership

Often, diverse ownership paralyzes initiatives to improve property and to upgrade seismic resistance because all the parties in the estate cannot agree. Likewise, after a disaster, the same paralysis affects proposals for repair. The problem is aggravated by the need to treat town blocks of historic buildings as mutually supporting structures in one coordinated scheme. Clearly there is a need to outline the responsibilities of private owners of historic buildings in a way that is compatible with legislation in order to achieve the objective of rapid action after a disaster.

Jones (1986a:73) describes the parameters of this responsibility.

> The cultural heritage of documents, artifacts, buildings and other structures constitutes a trust, not only for society at large but for generations to come, which is vested in the individuals and organizations who own or have charge of them. Trustees may be private owners or collectors, dealers, curators, archivists, librarians, superintendents, directors, boards, officials or legislative bodies. Until recently social attitudes towards trustees as regards depredations from natural disasters were nebulous. Consequently, responsibilities were ill-defined and policies either non-existent or vague to the point of being little or no use.

Disaster planning

Administrative measures, such as town planning, are important in both predisaster and recovery situations. However, reports on what actually happens during a disaster indicate that considerable improvements could be made in postdisaster operations, if there had been predisaster planning. The aim should be to establish communication and understanding between key people before the event. The military are sometimes called in because they are mobile, self-sufficient, and have good communication networks. There is a need to establish a permanent working relationship between disaster relief agencies and those responsible for cultural property.

Obviously there should be a prepared disaster plan for each area with a high risk. There should also be a check list of items that will be required immediately after the disaster so that organizations wishing to help can make useful contributions. Speed is the essence of the operation in case there is a second earthquake, the aftershock.

The risk to the infrastructure of lifelines, such as roads, drainage systems, water supply, gas, electricity, and other installations, should be assessed. Risk zones for landslips, soil liquefaction, and possible floods from dam bursts should be identified. Alternative routes for rescue teams should be studied and all usable helicopter landing sites located and mapped. Bypass roads to urban centers are essential as these communication hubs may become choked with debris.

Regional vulnerability will have to be assessed for different types and intensities of earthquakes. Studies of alternative scenarios will help establish priorities for action.

The actions needed to prepare seismic safety plans for historic buildings are summarized below.

1. Estimate seismic hazard in terms of the expected occurrence of earthquakes of various intensities and their return periods.
2. Estimate seismic risk (loss of life, material damage, functional loss, building degradation).
3. Identify structural systems and models for analysis for historic properties. Prepare record drawings and seismic survey forms.
4. Evaluate structural responses to earthquakes of various intensities.
5. Determine type and degree of damage for different predicted seismic intensities.
6. Develop alternative upgrading (strengthening) methods and estimate costs, applying conservation ethics to determine the minimum intervention necessary.
7. Develop plan schedules and give approximate estimates of costs of alternative schemes for different return periods.
8. Prepare a management plan for a chosen scheme. Obtain budget allocations based on accurate estimates. Execute desirable works to increase seismic resistance.

Emergency preparations

Preparations for an emergency should include establishing materials and equipment reserves at reception centers for movable property outside of seismic zones or at least 100 kilometers away. These centers can be used for other purposes prior to the earthquake.

Maps and documents such as inspection report forms should be prepared in advance together with earthquake damage assessment forms similar to the Yugoslav Montenegro forms (see Appendix 7).

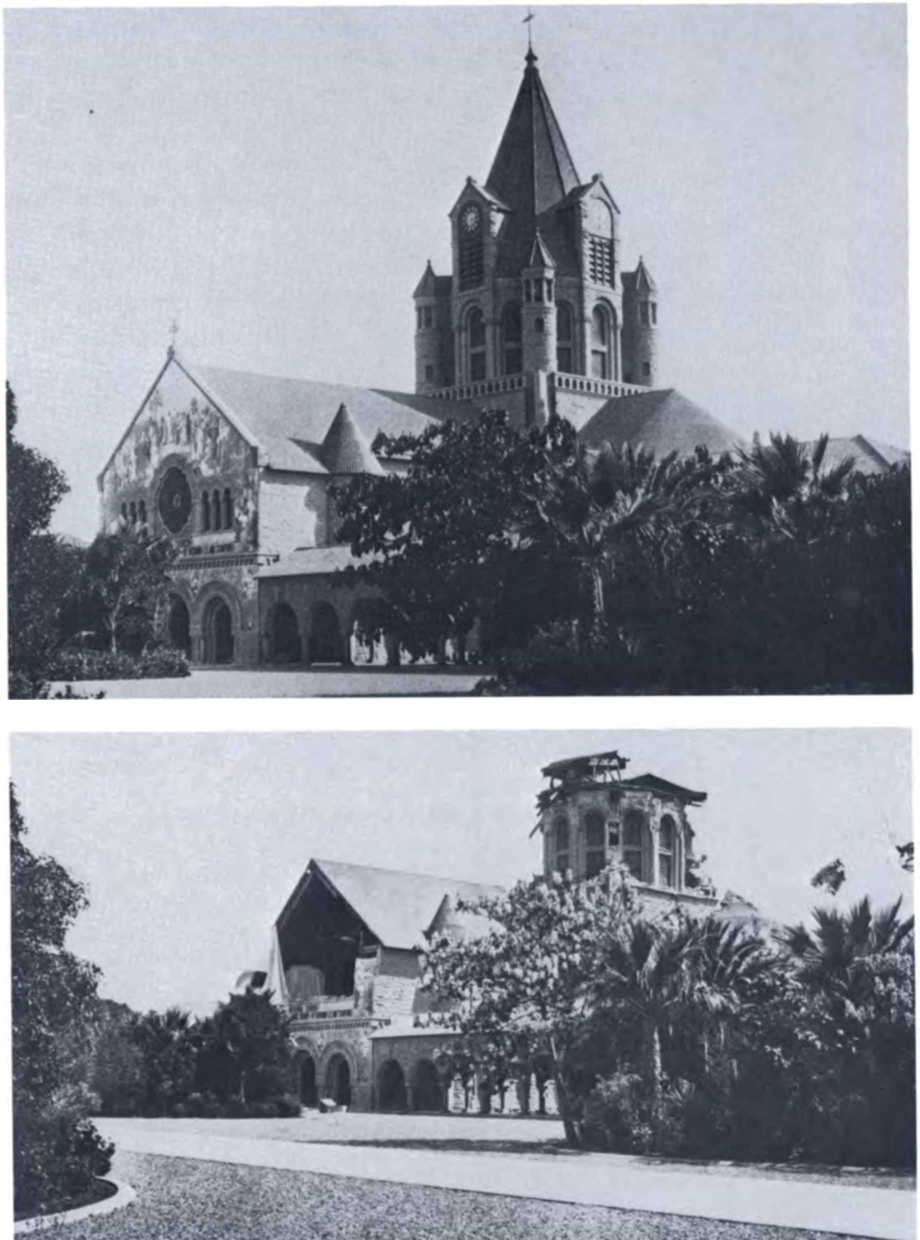

Figure 8. Above: Stanford University's Memorial Church was originally built at a cost of $1 million. Below: The 1906 earthquake demolished the fresco, which was later restored, and the bell tower, which was never rebuilt.

The effects of a disaster are greatly reduced if there is a disaster action plan, which will have to be rehearsed. Pichard identifies five important areas requiring attention: electricity, fire, vehicles, motor fuel, and advance preparations (see Appendix 12).

Rehearsals for fire should be held at periodic intervals and should include the local fire brigade. Such frequent rehearsals will keep staff and occupants on their toes, providing a good basis for other emergency drills.

Rehearsals of rescue operations for earthquakes have a much wider scope and should involve all relevant civil or military authorities. One great advantage of such rehearsals is that personnel get to know each other and jointly recognize the special needs of cultural property. Because personnel change, it is suggested that rehearsals take place at frequent intervals and concentrate on the strategic aspects of rescue of persons, buildings, and objects. Helicopters can be expected to play an important part in rescue, so all suitable landing sites with road access should be recorded.

Maintenance

Observation shows that well-maintained buildings survive much better than those that are poorly maintained. Indeed, it has been estimated that some 50 percent of the damage that occurs in an earthquake may be attributed to lack of proper maintenance. Pichard (1984:38) stresses the value of good workmanship.

> Regular and correct maintenance of monuments by the accepted methods of good preservation practice is even more important in earthquake areas than elsewhere. Experience gained in several earthquakes has shown that masonry properly repaired and maintained, even without precautionary strapping or reinforcement, has resisted with a minimum of damage and sometimes without any damage, whereas in the immediate vicinity buildings that were poorly maintained or not maintained at all were dislocated or collapsed. The vital importance of good upkeep means first and foremost that all monuments should be periodically inspected; any weakness should be noted immediately and remedied as soon as possible.

Inspections

Second only to the need for legislation and full documentation is the requirement for regular inspections with formal reports on the condition of historic buildings. These reports are the basis of a maintenance strategy that includes seismic upgrading.

Architects and engineers need specialized training to conduct these studies. With experience, they can diagnose the causes of decay and recommend preventive actions that will greatly reduce the cost of caring for historic buildings. In view of the importance of regular inspections and reports, which should be a basic administrative activity included in the preservation of our cultural heritage, the matter is dealt with separately in Appendix 6.

From the administrative point of view, it is important that the work needed should be classified under standardized headings as follows:

IMMEDIATE	to prevent danger to persons
URGENT	to avoid rapid decay
NECESSARY	to preserve the building fabric in at least a wind- and watertight condition
DESIRABLE	to rehabilitate or improve including anti-seismic diagnosis
UNDER OBSERVATION	to gain more information to make a correct diagnosis

Public education

The general public needs education with regard to seismic problems. The natural reaction is to hope that seismic disaster will not occur in its lifetime, yet there is no guarantee of safety beyond a reasonable assessment of the risk. Historic buildings are vital for a community's sense of cultural identity and continuity, so it is logical to give these priority in disaster precautions. The Administrator must make the public aware of the seismic risk that threatens historic structures.

Each step is beneficial as it wins lifesaving time. The most important step is to establish a maintenance strategy and to initiate seismic resistance measures as far as possible when major repairs, renewals, or alterations are undertaken. Guidelines for local builders should address appropriate measures for improvements in the vernacular construction. To upgrade the large number of buildings that give our cities and towns their particular "townscape" value, it is necessary to take steps to preserve traditional building crafts.

Preservation of craft skills

Without skilled craft persons, the architectural conservator is seriously handicapped. Yet, modern building technology based on factory fabrication and site assembly in a rapid and mechanized way does nothing to help preserve the crafts needed for the maintenance and repair of historic buildings.

Action is needed to preserve traditional crafts and trades. It is interesting to note that Japan, a country with a significant history of earthquakes, preserves its traditional crafts as part of the living cultural heritage. Action is also needed to secure the supply of traditional materials, of which suitable structural timbers are becoming more and more difficult to obtain.

Professional training

All professions involved in the conservation of historic buildings and objects need specialized training. No one profession, unaided, can solve the complex technical and cultural problems that inevitably demand consideration of several levels of risk and different levels of intervention.

Architects and engineers have to learn to think dynamically, and respect the cultural values of a structure. Architects have to coordinate the work of other experts and find the "least bad" proposal from the point of view of the historic building, which is the real client. Extremes of reconstructing the building or doing nothing to face the seismic risk have to be avoided, so through discussion each party will have to modify its attitude until an "optimum" design can be defined.

Incentives for maintenance

It is important to acknowledge that money invested in seismic risk reductions will ultimately give a good return in reduced damage and saving of lives. Other incentives include:

1. Tax incentives, such as those practiced in the United States, that, with minor modifications, can be made to apply to most situations in accordance with the Venice Charter
2. Inspection assistance for building owners to encourage protective maintenance

3. Subsidies for repairs and maintenance works to a minimum standard of "wind- and watertight," with structural integrity and improved seismic resistance
4. Support for organizations, such as the Dutch Monument Watch, that actually carry out inspections and repairs (The Dutch Monument Watch consists of a mobile workshop for first aid building repairs. Team members are trained to repair roofs, chimneys, spires, and towers and can report if major work with scaffolding is necessary.)

Money, whether public or private, invested in seismic risk reductions will ultimately give a good return in reduced damage and saving of life.

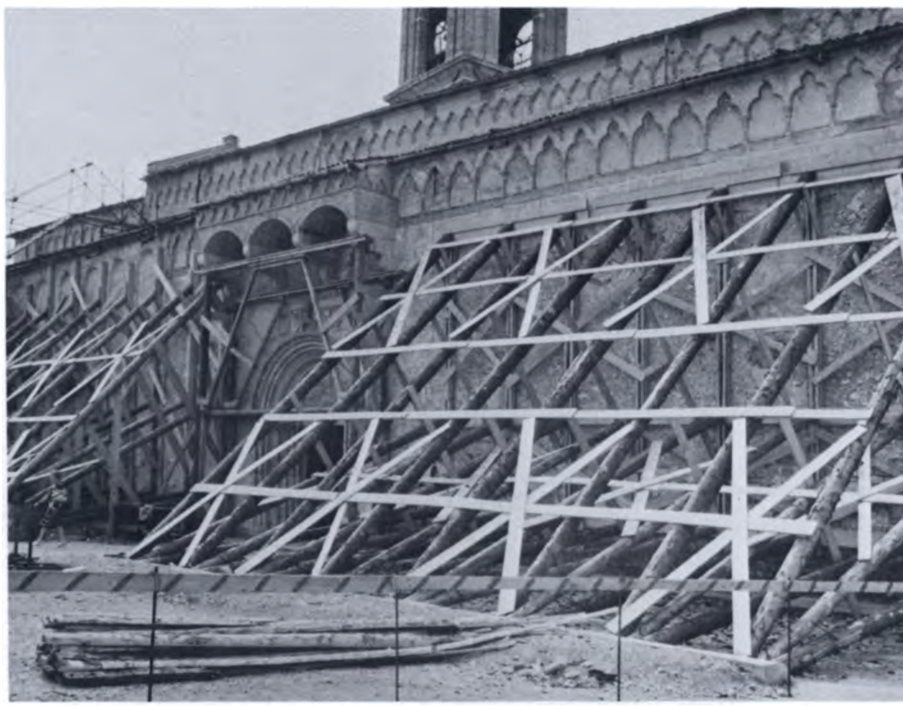

Figure 9. Exterior shoring of the cathedral wall following the 1976 earthquake, Spilimbergo, Italy.

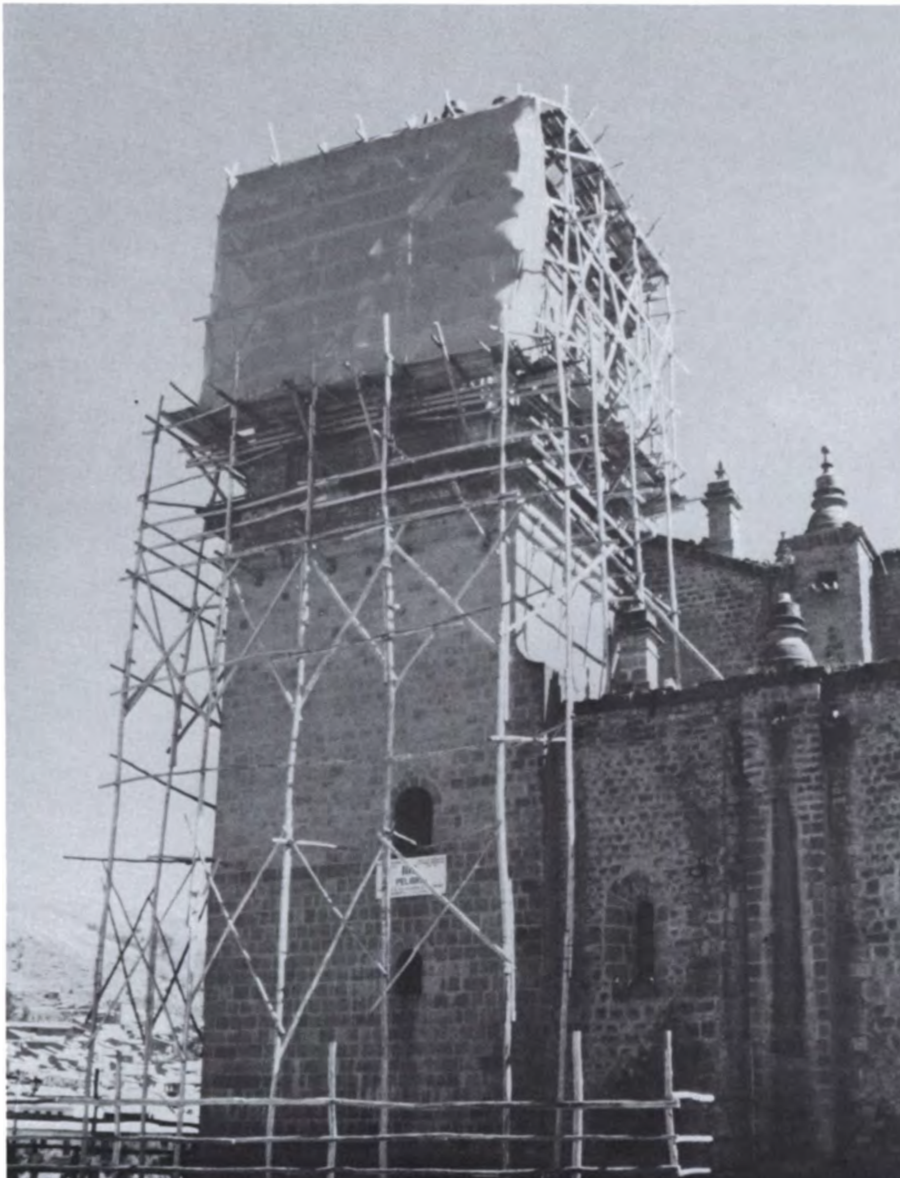

Figure 10. Scaffolding surrounds the reconstruction of a church tower that sustained damage in the 1979 earthquake in Cuzco, Peru. The present reconstruction phase is expected to take twenty years, a period during which at least one more earthquake is expected.

CHAPTER III

Emergency Action

Following an earthquake, there is great human shock. Obviously, priority must be given to saving life and evacuating casualties. Fires have to be fought and looting prevented. People must be fed and given shelter.

In the emergency situation after a major disaster, normal administrative channels may not be working and responsibilities may be taken over by relief organizations, the military, or the civil defense. These organizations have communications networks and other resources that may operate independently, bypassing existing institutional procedures. Disaster relief agencies and cultural property authorities do not yet have a tradition of cooperation. Thus, special guidelines for rescue actions in and around historic properties need to be incorporated into the plans of existing disaster relief agencies.

The emergency plan for an institution should be compatible with the overall local recovery operation. Specialized personnel, after attending to family and personal needs, should report to their institution to assist in recovery activities. These may include inspecting and assessing damage, securing objects from further damage from aftershocks, collecting broken fragments, protecting against water damage, dealing with flooding from broken water pipes, moving things in the event of approaching fires, etc.

Immediate action is necessary to protect valuable movable property, which should be labeled, taken to a previously designated safe place, and protected from looting. Shelters should be erected over historic buildings, especially those with valuable contents.

To avoid confusion, a central control point must be established where all conservation volunteers can report in order to ensure that their efforts are not frustrated. ICCROM can assist by coordinating international conservation aid, as was done in the case of the 1976 Friuli earthquake and the 1966 Florence flood. Schools of architecture and conservation training centers are important sources of volunteers.

Part of the shock syndrome is to assist in the destruction of what is left--arson is common, and wanton destruction of historic buildings that could have been saved is surprisingly frequent. In some countries, conservation organizations have enlisted the cooperation of military officers to organize security and firefighting measures. Earthquake protection could easily be added to these duties in seismic zones.

Emergency inspection

Quick inspection of the damage is essential. Dangerous elements must be made safe. Historic buildings should have been already marked with the Hague Convention symbol . A system of documentation was developed for use in rescue operations following the Montenegro earthquake. Internationally recognized color codes were superimposed on large-scale maps to show categories of damage. This system is provided below.

Usable: green	
Grade 1	slight superficial damage, virtually intact
Grade 2	superficial damage, nonstructural
Grade 3	superficial, light structural damage
Temporarily unusable: yellow	
Grade 1	structural damage, e.g., roofs and ceilings
Grade 2	serious structural damage to walls, etc.
Unusable: red	
Grade 1	severe structural damage, unsafe but capable of repair
Grade 2	partial collapse, e.g., roofs and floors
Grade 3	total collapse, requiring reconstruction of walls, etc.

The Yugoslav government also devised an excellent form for reporting damage (see Appendix 7).

Often there is external difficulty and danger in making an inspection. In such situations, a mobile photogrammetric unit would be of immense assistance in taking measurements and producing drawings without risk. Although this is technically possible, suitable equipment has yet to be developed.

Figure 11. Surviving roof and bell tower following the 1976 earthquake, Gemona, Italy.

Emergency protection

After an earthquake, temporary protection is vital. First aid will have to be given to buildings and objects.

Multidisciplinary conservation teams will need to be set up to prepare projects along the lines indicated in Chapter II. The cost of each proposal will have to be approved in accordance with budget provisions and priorities. There may be a delay of months or years, hence the importance of temporary measures. Standard forms will enable all the information to be coded and analyzed efficiently.

Priorities for repairs will be decided at a high level. There will be a need to present schemes and schedules to the public as well as to lay committees where axonometric drawings as well as models will be useful.

It is essential that experts in architectural conservation be involved to prevent unnecessary demolition of cultural property and unthinking removal of archaeological material. They must have the authority and means to make historic buildings safe by temporary strengthening and shoring.

Architects with sound engineering judgment and wide cultural knowledge are necessary for this work. Also, military engineers should receive special training for earthquake duties. Particular emphasis must be given to structural first aid.

The safety of working conditions will need constant monitoring. Helmets and dust masks should always be worn. If perishable foods are left too long in markets or cold stores, severe health hazards arise due to decomposition, so much so that gas masks and protective clothing become necessary. Rats and other vermin increase and make the difficult work of cleaning much worse. A similar but even more unpleasant risk occurs when it is the local custom to bury the dead in tombs above ground, for these disintegrate in an earthquake, scattering their decaying contents.

Adjustable screwed steel props together with salvaged timber are invaluable for quick work. Temporary roofing materials, in addition to polyethylene sheets, will be urgently needed to protect valuable objects that cannot be moved. Works of art such as frescoes that are part of a historic building should be protected against the elements and made structurally secure.

Archaeologists and art historians should be invited to inspect the ruins when safe, as many important discoveries can be made in their fields of activity.

Archaeological techniques should be used to establish a grid to locate all fallen pieces, which should then be stored in preparation for reconstruction.

Tubular scaffolding, mobile cranes both for inspection and for lifting threatening timbers or masonry, jacks, wire, rope, steel straps or chains with all necessary fittings such as corner pieces and turn buckles, and timbers for shoring are necessary in this phase, together with invaluable four-wheel drive vehicles. After full documentation, when repair work can start, the repair team will need light drilling equipment with an electrical generator, stranded stainless steel wire, grouting equipment, flat jacks, and special materials such as pulverized fly-ash, fluid coke, and epoxy resins. This is in addition to the traditional building materials: stone, brick, sand, lime mortar, timber, and roof tiles.

Movable cultural property

All movable works of art and other cultural property must be transported to safe storage outside the earthquake zone. First aid can be given to frescoes by the application of surgical gauze using a suitable reversible adhesive; similar treatment can be prescribed by a trained conservator for other materials. First aid to art objects is often necessary, and all organic material may need to be fumigated before storage in the depository. After fumigation, consolidation and reassembly will follow. A conservation laboratory with plenty of space but simple equipment is essential after an earthquake.

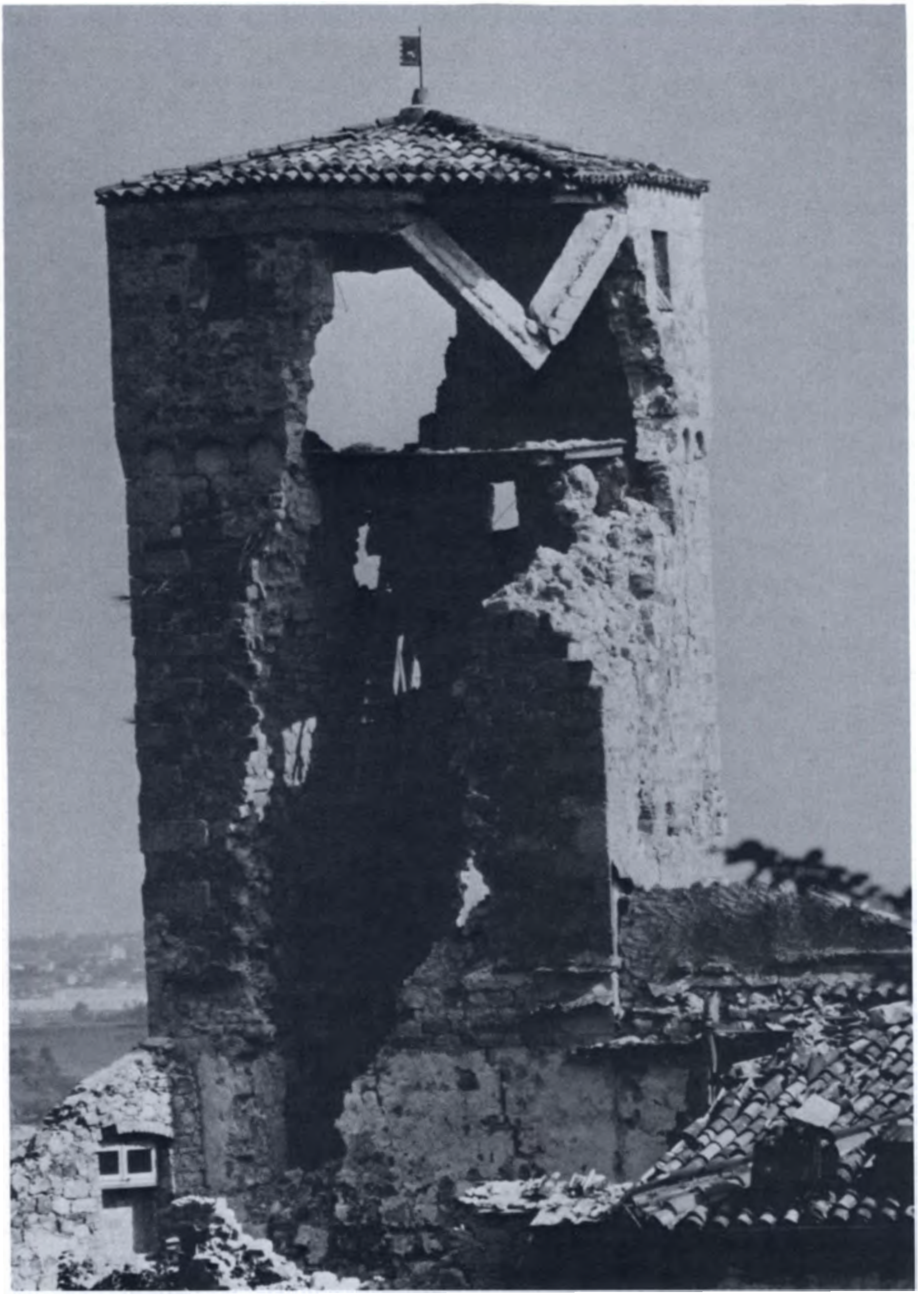

Figure 12. Damage to a castle from the 1976 earthquake, Artegna, Italy.

CHAPTER IV

After an Earthquake

In seismic zones, the strengthening of valuable cultural property should be included in the general program of preventive maintenance as and when economically possible, in conjunction with other major building repairs such as renewal of roofs or strengthening of walls and foundations. Often, in seismic zones, major maintenance efforts coincide with the repairs after an earthquake.

Well-maintained historic buildings have a relatively high degree of earthquake resistance. Bearing in mind that earthquakes and the reaction of historic structures to an earthquake are both unpredictable, the most profitable field of study is the analysis of previous earthquake damage in the locality. These case studies can provide the basis for future applications of strengthening measures as part of a general program of building maintenance.

Earthquake damage

The compatibility of the various structural elements and the availability of alternative structural actions when some elements fail are important considerations. The following is an imaginary scenario of earthquake damage: First, roof tiles begin to slip and fall, weak timber joints break and the roof timbers batter the walls, windows break and glass flies out. Then cracks form at the corners in walls, at points of stresses around door and window openings, and in vaults and arches. The center portion of an arch or vault may slip downwards, wedging and battering the structure apart. The roof falls in and portions of vaults andwalls, windows break and glass flies out. Then cracks form at the corners in walls, at points of stresses around door and window openings, and in vaults and arches. The center portion of an arch or vault may slip downwards, wedging and battering the structure apart. The roof falls in and portions of vaults and domes fall. Columns vibrate, crack, and batter each other. Pinnacles and towers rotate, shift, and collapse, and facades split apart. The structure disintegrates into large lumps if well built and into rubble if badly built. With simple vernacular buildings, the front walls tend to fall out into the street and the roofs crush the occupants. From examination, square, circular, and octagonal buildings seem to have the most resistant forms; rectangles, particularly if long, may have differential behavior at opposite ends, while projecting wings and features produce weaknesses. It is quite common to see buttresses sheared off walls.

The basic causes of damage are relative ground displacements and the inertia loads that result from ground accelerations. The factors effecting the seismic performance of a historic structure are its mass, stiffness, periods of vibration (all of which affect the loading), damping capacity, ability to absorb energy, stability margins, structural geometry, structural continuities, and distributions of mass and resistance. Historic buildings usually lack the ductility and structural continuity that can be designed into new buildings.

Operational procedure

After an earthquake, operational procedures must be adopted that are guided by the ethics of conservation and the principles of structural intervention. A list of possible concerns is listed on the following page.

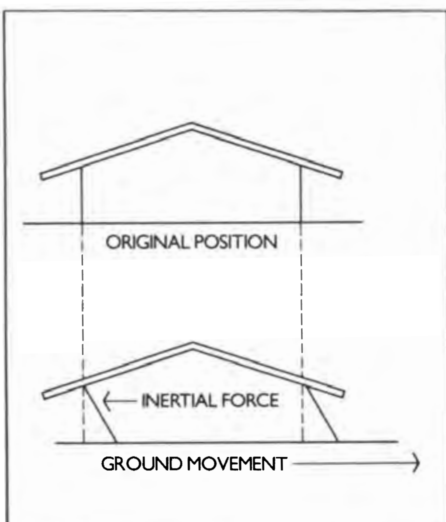

Figure 13. Seismic forces on buildings.

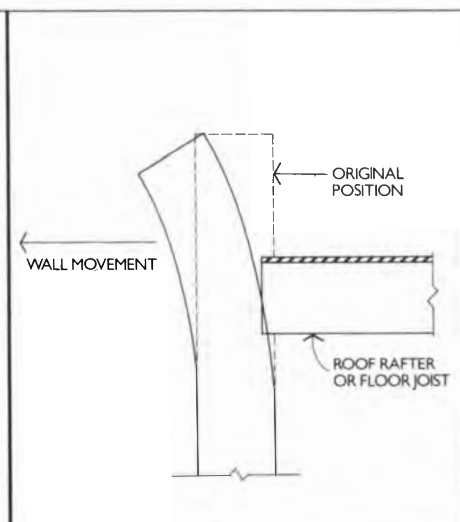

Figure 14. Typical structural failure.

1. Analyze the "values" in the building

Social	continuity identity spiritual and veneration symbolic
Cultural	archaeological architectural art documentary historical landscape scientific townscape
Use	economic functional political

2. Analyze the structural system: How many earthquakes has it already withstood? Were any of these greater than Modified Mercalli IX? Study records of past repairs and alterations when available.
3. Inspect the whole building and its surroundings. List all visible defects.
4. Review the causes of decay: natural or manmade. Is decay slow or rapid?
5. Decide how the structural system is working: the whole, the elements, and the materials.
6. Consider the building in its totality and determine other experts who are needed to assist with investigation and advice: engineers, soil mechanics specialists, materials scientists, archaeologists, art historians. Note that key experts must make a joint inspection of the building.
7. Consider new use proposals. Do they impose new structural requirements? Are they sympathetic to the building and its values?
8. Outline all alternative possibilities for action. Review techniques intended to increase the tensile strength without altering the dynamics of

the structural system, which might introduce new and possibly unforeseeable effects.

9. Consider the evidence in the structure requiring the proposed actions. Review the past performance of the building in earlier earthquakes.
10. Review the advantages and disadvantages of at least two probable courses of action in light of the theory of conservation. Are the values in the correct order of priority? Does the scheme prejudice future interventions?

Types of buildings

We should consider two classes of historic buildings: (1) modern (for their time) with high quality workmanship and materials; and (2) vernacular, which have evolved using materials available locally and which meet climatic conditions as efficiently as possible.

In vernacular architecture, improvements are possible using modern materials to increase tensile resistance and bonding, but a blind use of reinforced concrete can be disastrous. Much can be learned by failure patterns in previous earthquakes. Defects in vernacular construction should be studied, and guidelines with diagrammatic sketches should be given to local builders.

Modern buildings are more complex; it is impossible to generalize since each case is unique. Strangely, these buildings rarely include antiseismic elements except for metal clamps in masonry or ties across arched openings and vaults.

Four categories of construction are used in the Modified Mercalli Scale.

1. Good workmanship, mortar, and design; reinforced, especially laterally, bound together (using steel, concrete, etc.), and designed to resist lateral forces
2. Good workmanship and mortar; reinforced, but not designed to resist strong lateral forces

3. Ordinary workmanship and mortar; no extreme weaknesses such as failing to tie in at corners, but neither reinforced nor designed to resist horizontal forces
4. Weak materials, such as adobe; poor mortar, low standards of workmanship; horizontally weak

Materials

Perhaps Mercalli is unduly critical of adobe, which if mixed with long straw or tough grasses can achieve remarkably high tensile strength and durability. The mud mortar between the blocks may be the weakest element.

Timber structures are considered the most earthquake resistant among traditional forms, provided their joints are sound and the timber is not attacked by insects or fungi, but they are vulnerable to fires, which often follow earthquakes. Special attention should be given to self-contained fire protection installations similar to those developed for the Norwegian wood stave churches.

Masonry structures are generally considered less resistant to earthquakes unless the masonry is reinforced. Masonry materials--mortar and stones or bricks--are stiff and brittle, with low tensile strength, and are thus intrinsically not resistant to seismic forces. However, the earthquake resistance of masonry as a composite material can vary between good and poor, depending on the materials used. The Modified Mercalli Scale quite rightly lays a great emphasis on the quality of the workmanship of the original building. The structure's clinical history, including repairs and restorations, must also be taken into account.

Dynamic behavior

The dominant frequency of the earthquake shock and the natural frequency of the building and ground are vital factors. The stiffness of the building in relation to the properties of the subsoil should be assessed by a seismic engineer. The whole building will vibrate in a certain frequency (its natural frequency) due to its form and stiffness, and if this frequency is close to the natural frequency of the subsoil, there is dynamic resonance and the structural damage is much greater. Cracking and other disruption of the structure will change its natural frequency and may thus increase or decrease this resonance.

Historic buildings are generally stiff; they have short periods of vibration and are safer if they are on "long-period sites." The exceptions are tall towers, spires, and minarets, which are relatively flexible and more affected by long waves.

In a severe earthquake, badly bonded elements act like battering rams oscillating in different modes. It has been observed that a masonry building can survive a few shocks of great intensity, but that vibration of long duration is damaging. The first cracks divide the structure into various smaller parts with their own dynamic characteristics, which will vibrate in different ways and act upon each other in a destructive way.

Building investigation

A historic building may have already survived several earthquakes. This indicates resistance, but it may have been weakened. Lack of maintenance, injudicious alterations, and continual erosion of its resistance by combined causes of decay, including pollution and vibration, will also cause weakening with cumulative effects. These can only be countered by regular inspections and a maintenance and repair strategy.

A historic building can only be understood through a study of its history, including the sequence of construction, details of previous repairs and restorations, and earthquakes. On detailed inspection, needs should be assessed under the headings: IMMEDIATE, URGENT, NECESSARY, DESIRABLE, and UNDER OBSERVATION (see Chapter II).

The dynamic behavior of the building should at least be visualized and, if possible, tested. This can be done by locating accelerographs in some significant places on the structure to register its movement under the influence of ambient vibrations or forced vibrations produced by special vibrators. This indicates which parts are likely to disassociate themselves first in an earthquake. Then, stress concentrations at doors and windows should be considered so that these elements can be strengthened. A check should be made to see how well the structure is tied together at floors, cross walls, and the roof level.

Improvement of earthquake resistance

The principles of repair should be to restore and improve the building's capacity to resist an earthquake, enabling it to absorb seismic energy without serious damage. The principles of conservation must always be followed. The character of ensembles must be recognized and this includes the way they were

Figure 15 Above: unachored portion of building collapses in 1983 Coalinga earthquake. Opposite: anchoring of floor joists stabilizes wall.

lived in and utilized. The value of full documentation as a basis for scientific repair work cannot be overemphasized.

Structural strengthening of historic buildings is a subject that is not yet well defined and where much fundamental research is still needed. Useful guidelines are given in Appendix 8.

Antiseismic strengthening of the structural system is provided by increasing structural resistance and/or ductility of certain structural members within the existing structural system. Miodrag Velkov (1985:2) writes:

> The solution for repair and/or strengthening depends on many factors like local soil conditions and seismicity, type and age of structures, damage degree and type of damage, available time, equipment and staff, preservation and architectural conditions and requirements, economic criteria, as well as the necessary seismic safety. Making repair and strengthening decisions is a very responsible and serious task in the process of revitalization of historic buildings struck by an earthquake.

All interventions, except possibly strengthening foundations when there is archaeological supervision, cause some loss of cultural value in the historic building; minimum intervention to accommodate an acceptable risk is therefore best. This can only be decided by an interdisciplinary team examining and evaluating alternative projects.

The final recommendations of the "International Course on Preventive Measures for the Protection of Cultural Property in Earthquake Prone Regions" organized by IZIIS (The Institute of Earthquake Engineering and Engineering Seismology of the University Kiril and Metodij in Skopje, Yugoslavia), together with ICCROM, give useful guidelines (Appendix 9).

Building codes

Since the art of designing earthquake-resistant structures is in its infancy, most codes are still based on gross simplifications, using subnominal horizontal loadings or base shears as the design criteria for new buildings. It is the considered opinion of experts that such codes should not be applied to historic buildings of different structural types, and it must be stressed that no historic building should be condemned to destruction or taken out of beneficial use because it does not or cannot comply with the current official code; with expert design and special techniques it can be strengthened. Many factors outside the code

Figure 16 The Arch of San Francisco in Antigua, Guatemala, undergoes restoration efforts following the February 4, 1976, earthquake.

must be taken into consideration, preferably starting with a ground movement seismic spectrum.

After an earthquake, examination of typical collapse sequences should be made in order to rectify defects in traditional local construction. Regional practices should be accepted where they have proven to be good, but where they have failed, they should be improved with modern techniques.

Each historic building requires individual and meticulous inspection of the fabric. A study of its previous repair history and preventive maintenance are the first steps, followed by such strengthening against dynamic forces as is practical and economic, in conjunction with its overall conservation plan, which gives a reasonable approach to prolonging its life and reducing the earthquake danger to its occupants.

One must consider the sequence in which damage has occurred, how it might extend, and how it might be prevented in the next earthquake. There is rarely a single correct answer to structural problems, so several alternatives must be considered and costed. Each historic building must be treated as a special problem. The fabric of the building should be considered as a whole to avoid disintegration of efforts into mutually destructive parts.

Foundations

Earthquake shocks are transmitted to the building through its foundations. If the foundations fail, the results will be disastrous, so foundations should always be investigated. If the water table is high, the danger of soil liquefaction is greater, so the possibility of natural drainage should be considered.

If a building rests on sloping strata or variegated soils, for example, peat and clay, special measures will be necessary, such as pilings of varying depth to support the whole building on a sound stratum not liable to liquefaction in an earthquake. The pile caps must be linked with horizontal beams and carefully secured to the existing structure. In other cases, it may be sufficient to unify the foundations with ground beams around the perimeter. For this work, reinforced concrete is the legitimate material, provided sufficient cover is given to the steel bars to prevent corrosion.

Separate architectural elements

Tall chimneys have a different mode of vibration from the main building and are liable to collapse first, causing damage and perhaps weakening a vital part of the structure. They should be strengthened when possible by vertical drilling and the insertion of prestressed ties or, if in poor condition, by being rebuilt with vertical reinforcements anchored securely to the wall below. Architectural elements, such as asymmetrical towers, should be completely separated from the main structure by a gap to avoid battering. Also, sculpture and landscape ornaments will need special fixings to properly secure them during an earthquake.

To prevent mechanical plants from sliding, overturning, and jamming during an earthquake, clearances from 20 millimeters to 40 millimeters may be necessary. There must be flexibility in connections with pipes and wires, and their fixings must be strong enough to withstand three-dimensional movements. Electric mercury switches are dangerous because vibration may activate them, and heating boilers with firebrick linings are also liable to damage. Lifelines, such as water and electricity, to hospitals and firefighting services, need special protection and should be examined by specialists.

Connections

Examination of earthquake damage shows that bonding of walls together at the corners is vital, together with the tying of floors and roofs to walls. The insertion of lightweight tensile reinforcement, with some degree of prestressing to bond elements together, gives the masonry of historic buildings greater earthquake resistance without altering the structural system.

Experiments have shown that adobe or mudbrick with diagonal prestressed cables anchored at top and bottom has much greater resistance to dynamic forces. In existing adobe buildings, reinforcement in the form of diagonal galvanized steel wires might be added under the layer of mud plaster that is normally renewed and anchored with small elements of reinforced concrete at the top and bottom.

For simple two-story masonry houses built with lime mortar, Kolaric (1977) recommends reinforcement in both directions using 16 millimeter steel ties fixed to the floor joists and anchored with 150 by 150 millimeter plates, 5 millimeters thick, which are recessed into the external walls and then covered with plaster. Similar strengthening should be done at roof level where the anchoring of wall plates and tying together of roof timbers should be given special attention, as earthquake damage often starts at this point. The falling of heavy roof tiles and collapse of roof and floor timbers are one of the main causes of the loss of life, generally preceding or promoting the collapse of walls. The roof structure should incorporate diagonal ties, which can be used to strut gable walls, and roof tiles should be securely fixed with rustproof screws or nails.

Structural elements

The condition of the mortar may be as important, or possibly more so, than the quality of the original workmanship. Repointing, grouting, and replacing defective mortar are common remedies, but in extreme cases reconstruction may be the only available course. Considerable strengthening of masonry buildings can often be obtained by grouting procedures of all types using hydraulic limes. In special cases, the use of expensive polyester and epoxy resin grouts is justified. Such grouts can be used following normal injections, thus exploiting their penetrating power to fill fissures and fine cracks and avoiding the necessity of filling large voids with costly materials. Rough masonry walls that are plastered can be strengthened in the way suggested for mudbrick, or by applying galvanized steel mesh on to both faces and tying the faces together at about 1 meter centers, and then replastering.

Plaster of wattle-and-daub-panels in timber constructions can be strengthened with galvanized expanded metal reinforcement applied to both sides and, if possible, nailed to the framing timbers if they are not exposed. Such panels can also be consolidated by grouting.

Cross walls and partitions must be securely attached to the main walls. Lintels over doors and windows should extend at least 400 millimeters beyond the opening to give added protection. If doors and windows are so placed as to cause a weakness in the wall, long reinforced concrete ties may have to be inserted so as to disperse the concentration of stress that occurs at their corners.

Archaeological sites

In seismic zones, archaeological sites will need special conservation excavation, unless they are backfilled with earth. Archaeological monuments consisting of stone facing with earth fill are particularly vulnerable if the jointing of the stone is in poor condition. Indeed, many archaeological sites were reduced to rubble in the 1976 Guatemala earthquake, because they were exposed to risks that had not existed prior to their excavation. Consolidation or rebuilding may be necessary, in which case photogrammetric records and numbering of stones on an elevational grid, as was done at Machu Picchu, will be necessary.

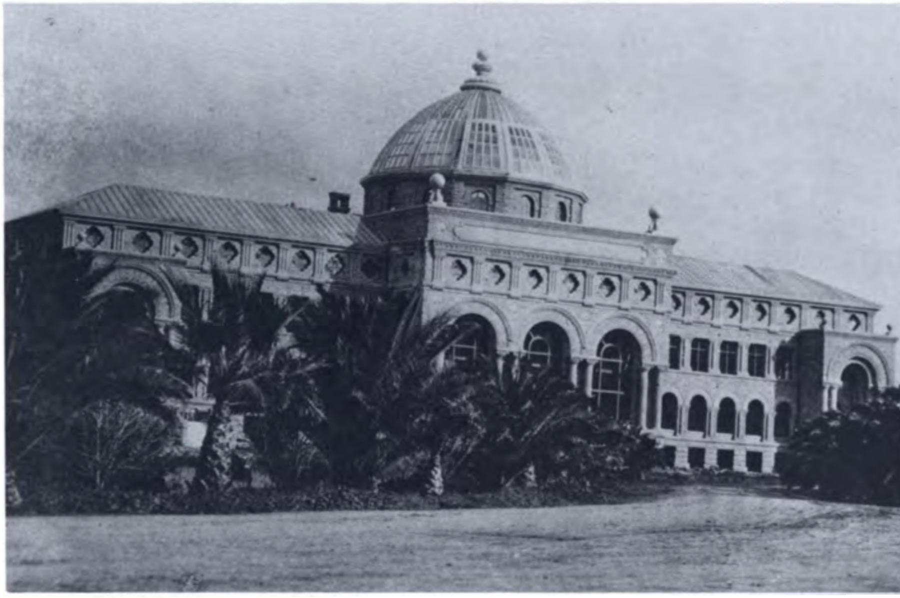

Figure 17 Above: Stanford University's domed library shortly before the 1906 earthquake, Palo Alto, California. Below: Damage was so extensive, the building was later completely demolished and never rebuilt.

APPENDIX 1

FIRE PROTECTION OF HISTORIC BUILDINGS

Fire protection is essential for historic buildings and is based on good housekeeping, training, and rehearsals, which teach people how to act in an emergency.

Fire is no respecter of historic buildings, nor do regulations and codes for fire protection and earthquake strengthening respect the cultural and artistic values in historic buildings. The aim of the firefighters is to protect life. The conservator's aim is to prevent fire and minimize damage caused by earthquakes, which in fact also protects life.

The main problem areas in historic buildings can be summarized as follows:

1. Flammable decorative materials and furnishings
2. Accumulation of dust, dirt, and rubbish in roof and storage spaces
3. Deficient fire resistant walls, floors, and doors
4. Lack of compartmentation and internal subdivisions, c.f., open stairways
5. Inadequate means of escape through alternate doors, passageways, and staircases
6. Lack of master keys; obsolete locks
7. Faulty electrical installations
8. Faulty chimneys with soot and grease accumulations
9. Poor standard of management and housekeeping
10. Failure to consult fire prevention officers and failure to organize regular fire drills
11. Danger arising from arson, smoking, and cooking operations

The required fire resistance for walls, floors, and ceilings and doors depends on the height of a building and its area. The United Kingdom legislation demands the following resistances:

Height	Area	Resistance
Single story	less than 3,000m	1/2 hour
7.5m	less than 500m	1/2 hour
15m	less than 3,000m	1 hour
28m	1,000-7,000m	1 hour
28m	more than 7,000m	1 1/2 hours

Distances to the nearest protected escape route should not exceed 20m.

When use is changed from domestic to public, often the resistance of specific elements has to be upgraded. This can involve structural alterations, which also give an opportunity for seismic upgrading.

Reduction of the "fire load," that is, the amount of combustible material, is an important consideration. In addition the flammability of furnishings should be reduced with the advice of a conservator. The possible spread of fire in rooms must be considered, together with its spread from room to room and floor to floor.

The occupants should practice fire drills, preferably twice a year at different times of day or night. After assembly, able-bodied persons can attack the fire with extinguishers and hose reels after the electric mains have been switched off in order to avoid electric shocks. Gas mains should also be shut off. There is danger in an earthquake that water sprinkler systems might be activated causing more damage.

Extinguishers should be located in strategic places inside the building and also at the assembly point, which, in seismic zones, should be specifically strengthened against collapse. Extinguishers are of various types with special functions. Each has advantages and disadvantages. A general categorization follows.

Water	Effective against solid combustible materials, i.e., wood, pasteboard, fabrics. Dangerous for electrical and flammable liquids.
Dry Powder	For general purposes, but generally effective against liquids and flammable substances. Does less damage to furnishings, but messy to clear up.
Carbon Dioxide	Essential for electric installations. Useful against flammable liquids and gases. Dangerous to user in confined spaces.
Foam	Useful against solid combustible materials and flammable liquids such as fuel oil.
Halon Gas	Useful against all types of fire except light metals False alarms can be expensive. Damage to valuable objects minimal.

The plans of a building showing its construction are specially valuable to the fire fighting teams. Compartmentization reduces the spread of fire, especially in roof spaces.

With skill, seismic upgrading of the historic building can be incorporated in fire resistant designs.

After a fire or earthquake, a conservator must rescue objects and arrange for their fumigation and treatment. The damaging effects of firefighting practices should be considered. For example, a building must be well ventilated after receiving a great deal of water to allow the fabric to dry and to prevent fungal attack.

Check Lists

Premises should be thoroughly checked in order to establish and maintain reasonable fire safety standards. The check lists below provide a useful start for a wide variety of different types of buildings. They should be added to and altered to suit the particular premises concerned. Checks, as appropriate, should be made: (1.) at the beginning of each day, (2.) at close-down or at night, and (3.) periodically (major checks required at less frequent but regular intervals).

Arson

- ☐ Premises adequately supervised
- ☐ Waste, flammable liquids and stores kept away from and out of easy reach of visitors and passers-by
- ☐ New casual staff working under supervision
- ☐ Doors, windows, fences, gates in good repair
- ☐ Buildings and gates secured against intruders at the end of the day

Workmen

- ☐ "Permit to work" system adopted
- ☐ Smoking prohibited in danger areas
- ☐ Blowlamps, cutting, welding, bitumen boilers, other heating processes and rubbish burning only allowed by agreement
- ☐ Combustibles removed or protected before work starts
- ☐ Checking procedure instituted for detecting smoldering fires after work ceases
- ☐ Fire extinguishing and alarm facilities available
- ☐ Fire procedure explained to workmen

Heating installations

- ☐ Flues and hearths adequate and sound
- ☐ Chimneys swept regularly
- ☐ No kindling, rubbish or other combustible materials kept in boiler room

- ☐ Gas and oil fired boilers and furnaces serviced regularly
- ☐ Fire valves (oil-fired boilers) fully operational
- ☐ Heaters clear of combustible materials
- ☐ Guards in position
- ☐ Portable heaters safely located (away from doors, curtains, beds, furniture)
- ☐ Oil heaters:
  - clean and maintained
  - filled in outbuilding
  - away from draughts when lit
  - never carried when alight

Cooking

- ☐ Cooks reminded of:
  - the dangers of fat fires
  - not to leave the kitchen when frying
  - how to tackle a fat fire
  - fume extraction systems cleared regularly

Electrical equipment

- ☐ Electrical installations inspected and tested every five years
- ☐ Faulty equipment turned off and replaces
- ☐ No worn flexes
- ☐ No overloaded circuits
- ☐ Combustible materials kept clear of lights
- ☐ Indicator warning lights for pressing irons, work benches, etc.

Electricity generators

- ☐ Overhauled and serviced regularly
- ☐ Petrol and oil stored safely away from building
- ☐ Ventilation unobstructed

Smoking

- ☐ Sufficient ashtrays provided
  - store rooms
  - roof spaces
  - within six meters of petrol storage
  - other danger areas

- ☐ "No Smoking" notices in position

Waste and rubbish

- ☐ All parts of premises clear of waste and rubbish
  - store rooms
  - attics and basements
  - plant rooms
  - staircases and under stairs
- ☐ Waste awaiting collection stored safely
- ☐ Rubbish burning carefully supervised

Means of escape

- ☐ Means of escape unlocked and unobstructed when people are in building
- ☐ "Fire exits" clearly marked and sign posted

Fire alarms

- ☐ Fire warning systems tested regularly
- ☐ Call points and detectors unobstructed
- ☐ Systems regularly maintained

Fire extinguishing equipment

- ☐ Extinguisher, hose reels and buckets in position and unobstructed
- ☐ Static water supplies maintained

If fire should break out

- ☐ Instructions prepared detailing the action to be taken by staff on discovering a fire and when warning of fire is given
- ☐ Staff know these instructions and taught
  - how to raise the alarm
  - how to call the fire brigade
  - how to use the first-aid fire equipment
  - how to evacuate the premises
  - Fire drills held regularly

Last thing at night/at close down

- ☐ In historic buildings most large fires occur at night, after people have gone to bed. The following checks should be made:

- ☐ Open fires are safe (with spark guards in position) and space heaters, stoves, lamps, etc. turned off
- ☐ Storage or other convector heaters do not have anything draped over them to impede circulation of air
- ☐ TV sets and other electrical appliances not required to be "on" are switched "off" and plugs removed from sockets
- ☐ No cigarettes are left smoldering
- ☐ All doors are closed
- ☐ The building is secured against intruders

APPENDIX 2

COMPUTERIZED LISTING

Conservation of historic buildings has moved from consideration of individual cases through the field of planning into that of management of our cultural resources. Criteria for listing and recording have changed and expanded as our knowledge and expertise increase.

The old lists, several of them differing, presented enough in the way of clerical headaches and administrative confusion. Now we have the possibility of computerizing compatible lists.

In a fully developed system the following typical questions, among many others, could be answered immediately:

1. Who owns the building? Is it occupied? By whom?
2. Who built the building? When?
3. Who was the architect? How many other examples of this architect's work exist in the area?
4. What documents relate to the building? Where are they to be found?
5. What are the special features of the building? How many examples of these features exist in the area? Are there any similar buildings?
6. Did any historical events take place in or near the building?
7. Have any alterations been made?
8. What materials are used in the building's construction? Do these represent special workmanship or technique such as timber jointing?
9. Is the building subject to any threats? Pollution? Traffic? Neglect? Vandalism?
10. What is the cost of repairs and maintenance (subdivided into the standardized categories of Immediate, Urgent, Necessary, and Desirable)?
11. What grants have been made in the past? Is grant-aided work in progress? Or has a grant been promised?

Collation of the answers to the relevant questions would enable the Administration to plan its conservation policies based on up-to-date and complete information.

The first eight questions are valuable data for planners and architects. In addition the system could address an additional nine questions for the archaeologist:

1. What sites or buildings are threatened by road plans, building operations or other causes?
2. What building projects affect archaeological areas?
3. How many sites in the area belong to specific archaeological periods?
4. How many sites are scheduled?
5. How many known sites have not been scheduled?
6. How many sites are under guardianship?
7. What sites are subject to agricultural agreements?
8. What sites are subject to vandalism and theft?
9. What is the order of priority for excavation or investigation?

The number of questions an art historian could ask is legion. The database would, however, save him tedious chores. In fact, the computerized database is the ideal vehicle for historical research, published or otherwise, as it can make information immediately and widely available.

APPENDIX 3

PHOTOGRAMMETRY AND EARTHQUAKES

The measurement technique of photogrammetry can be invaluable for recording in seismic zones. In the first instance, it can be used in the conventional sense to provide archival records of cultural resources which are likely to be affected, long before any catastrophe has happened. However, it has a second value in that immediately following an earthquake it can be used to obtain at high speed records of partially collapsed structures, or those that are so dangerous that demolition is inevitable, without even approaching the structure.

Before giving specific advice on the application of photogrammetry in these two ways, some general background will be given for the benefit of those unfamiliar with the techniques. Photogrammetry is the science of measurement from photography. The principle of the method can be described in very simple geometrical terms. If in a triangle two angles are known, and the distance between, we can compute a coordinate value of the third point. This principle is of course used extensively in conventional surveying, where with a theodolite or transit we measure angles to a point from the ends of a known base. However, a camera can also be likened to a theodolite. The centre point of the camera lens corresponds to the centre point about which the theodolite rotates. Therefore, any point imaged on a photograph by a ray of light passing through the centre of the camera lens defines a horizontal and vertical angle. If we take two photographs of an object, with a known base distance, we now have enough geometric information to define coordinates of points on the object.

Two items of equipment are needed to make this process into the accurate and precise science of modern photogrammetry. Firstly, a camera, which is carefully constructed so that its geometric characteristics are defined, and which we refer to as a "metric" camera, and secondly a stereo restitution instrument, or "stereo-plotter," into which the pair of photographs is placed, and from which we can subsequently derive the necessary measurements.

The general application of photogrammetry in architecture is now well established, and is in regular use in many countries. The process is normally used to provide line drawings of elevations of facades, for renovation and conservation, for historical research, and for creating a record or archive of material. In regions threatened with seismic movement, it is this latter category of recording which it is particularly apposite to consider. For in making an archive, we do not need to carry out plotting at once. The photographic negatives, and the associated measurements for scale and datum, are the primary record. The more time-consuming and expensive part of the process of producing line drawings can in fact be postponed more or less indefinitely, with the sure knowledge that in the event of a catastrophe the photographic records can be examined and measured.

Recording by photogrammetry

Photogrammetry can therefore provide what is probably the most thorough and secure method of recording structures. However, it should not be seen as a method on its own, but should form part of a policy for recording in earthquake zones. Conventional photography, hand drawing of details of architecture, the preparation of plans and sections, the written record and the analysis of materials, will all clearly form part of a total record. However, where time and resources are limited, it is considered that photogrammetric recording should immediately form a substantial part of a programme of primary recording. Only those experts in a particular culture can make the final decision on what it is important to record and in what detail, but in general an archive will be of greater value if it has primary stereo-cover for many buildings rather than a total record for only a few.

However, even with photogrammetry, a balanced view must be taken of which technique, and to what degree of thoroughness recording will take place. For the most important buildings, such as cathedrals, palaces, castles, indeed those buildings which are irreplaceable in that culture, thorough stereo-recording should take place. As far as possible all facades and surfaces should be recorded, without assumption as to regularity or repeatability. The purpose is to create a definitive record, in an archaeological sense, where even the obscurest item is recorded. Nor should interiors and ceilings be neglected, particularly in churches, and in the principal rooms of important buildings. For a second category of buildings, somewhat lower standards may be accepted: smaller photo scales, less control measurements, more assumptions of repeatability. For the lowest class of building, e.g., streetscape, the simpler and cheaper process known as rectified photography may be quite adequate. While a photogrammetric process, this method does not utilize stereo-photography, but instead relies on individual photos taken, "square-on" to the facade, and printed to scale. In conclusion, a photogrammetric archive built up by adhering to these principles will provide an invaluable record of a nation or region's monuments. If the building up of the archive can be achieved in conjunction with even a small programme of plotting of drawings, photogrammetry will also be seen by conservators and others involved in renovation to be making a positive contribution to the repair and maintenance of monuments.

Regrettably, we must face the inevitability that at sometime, somewhere in a seismic zone a catastrophe will occur where records of the built cultural heritage will be inadequate or non-existent. Here photogrammetry has four attributes which make it the "sine qua non" of recording techniques: the tremendous amount of data which can be encapsulated in one stereo-pair of photographs, the speed with which stereo records can be obtained, the relative safety of obtaining the photographs and lastly, from this photography, the technique can provide rapidly and accurately outline drawings, which may be invaluable in analyzing the structural condition of the building. In the event of demolition, a record if even partial is obtained of what was there. If the building can be saved, the survey has been safely obtained which will be essential for its repair.

Important new developments in photogrammetry, brought about by the widespread adoption of digital computers, are taking place, so it is most important to obtain advice which is up to date when considering adopting photogrammetry. CIPA, the International Committee for Architectural Photogrammetry, in conjunction with ICCROM has made a special study in recent years of the applicability of photogrammetry in the circumstances described above. Indeed, the two bodies were actively involved in recording in the commune of Venzone, following the disastrous earthquake in Northern Italy in 1980, and since then have considered the more general problems. CIPA can give advice on policies for archival recording, as well as in emergencies, and can be contacted through ICOMOS Headquarters in Paris.

A guide to photogrammetric surveys

The guide sets out in a step by step fashion the detailed aspects of the recording process and peripheral interests where those come to agreement and understanding. It gives advice on the best procedures to be adopted in particular circumstances and highlights not only the advantages of certain systems but also their inherent limitations. Finally, a check list which can form the basis of communication between the client and customer is provided.

Definitions

Stereophotogrammetry is the process where architectural detail is drawn off a "stereopair" of photos. These photos are normally taken with specialized metric cameras, and the plotting is carried out through a stereoplotting machine of the type derived from aerial survey. The most common product of this process is the line drawing of a facade, showing various levels of detail, and drawn out to a high level of accuracy.

Rectified photography is another process "borrowed" from air survey. Photographs are taken preferably parallel to a facade, and then printed exactly to a pre-determined scale. Alternatively, if tips and tilts are present, these are removed at the printing stage. The advantage of the process is that a scaled photographic image is presented. The main disadvantage is that any "depth" on the facade will lead to scale and displacement errors, thus accurate measurements cannot be made from the product.

Hand measurement refers to any process of measurement on a facade which does not involve the principal measurements or recording being derived from photography. Traditionally, measurement would be by tape, plumb-bob, and level. Nowadays, modern survey instrumentation such as electronic distance measurement equipment can be invaluable in providing a framework. Although these notes concern photographic measurements, the possibility of applying hand measurement techniques should not be neglected: for a simple facade, or a simple problem, they may be quicker and cheaper.

Types of survey drawings and records

We have identified the principal areas of application where we feel that photogrammetric techniques should be considered. In each case, we identify the main plus and minus points in their application.

1. Archival records, of structures, which might be needed for example as a historical record in their own right, or before demolition or before extensive alteration. Line drawings may be required, but an option here is to take stereo-photography only, and store this, in the knowledge that plotted elevations can always be prepared.
2. Archaeological/Historical investigation: base plans and elevations for building history analysis where very fine detail, and considerable annotation of stone type, mortars, etc., are recorded. Here, 1:20 scale photogrammetry drawings often seem most suitable.
3. Fabric analysis: Survey drawings produced prior to repairs as a record of the existing state of the fabric and as an instructional tool for remedial work. Either photogrammetric drawings or rectified photography may be satisfactory, according to the problems and the nature of the fabric. For example, on flintwork, rectified photography would probably be the best product. On an ashlar building, with "depth" variations photogrammetry may be more suitable.
4. Structural analysis: location of deformations and structural dynamics for periodic monitoring. Framework drawings for data recording from other survey techniques. Swift recording system for emergencies. Horizontal and vertical sections possibly needed as well as elevations. Photogrammetric drawing (or coordinates only) will undoubtedly be necessary for these cases. However, it should be noted that if structural movements of less than 5 millimeters (0.2 ins) are being investigated photogrammetry will usually be very expensive to employ.
5. Planning tool: for townscape analysis including recording of streetscape; the alignment of scaled elevations and the relationships between old and new construction. Here, rectified photography may often be sufficient, as low levels of accuracy will usually be acceptable. Also, photogrammetric cover in narrow streets can be expensive.

Products

The recorded information can be stored or displayed in various ways: one of the assets of photogrammetry is the flexibility which the method offers.

a) Do you need a drawing at all? For some purposes the stereo-photographic record alone may suffice. If you purely wish an archival record of what is there, or if there is some likelihood of legal problems, or if you simply wish to study the surface and do not need drawings, stereo-photos alone can be invaluable.

b) A line drawing produced photogrammetrically is perhaps the commonest product. However, different levels of detail can be drawn out, generalized plots can be obtained by omitting much detail while plotting.

c) Rectified photography provides a photographic image but lacks accuracy. It can be presented as straightforward bromide prints, which give the best detail, but present reproduction problems. Alternatively, the image can be printed onto clear film, which can then be dyelined.

d) A composite of photogrammetric linework and rectified photography overprinting can be very successful. For example, on a brick building, drawing of individual bricks could be too expensive, and still not show subtle variations in the brickwork, but knowledge of deformation could be important. Here, the "composite" may provide a suitable solution.

e) The photogrammetric line drawing can nowadays be easily "digitized": the product is a magnetic tape. With CAD/CAM (computer-aided design and computer-aided manufacturing) systems becoming increasingly common, the use of this type of product will grow. However, it may be necessary for the client to categorize the data into features, e.g., major architectural elements, stonework joints, window details, etc., if the greatest value is to be obtained from this form of presentation.

Interpretation

The stereo-plotter operator's knowledge of architectural detail and the perception of that detail when viewed in the plotting machine will affect the product as reproduced on paper. Also, dependent on the type of drawing required the level of detail may be amended. For example a medieval building being amorphous is likely to require more recording than a classical elevation where detail is ordered to a known grammar and based on symmetry. Does every detail have to be drawn?

Presentation

There are different ways in which the photogrammetric output can be presented. The drawing directly from the plotter is called a machine plot, and usually has rather a flat, mechanical, and slightly unfinished appearance. The product can be supplied in this form, but most clients will require "hidden" details, etc., to be completed. Also, emphasizing of the major elements may be incorporated by hand draughting work at this stage.

Different photogrammetric plotting systems can also produce a different appearance for the drawing. Continuous line plotting produces the most thorough and complete recording. Point by point system drawing will usually lead to a generalization of features, but is of course cheaper to prepare.

Establishing scale and datum

An important part of the survey work is the process of establishing scale and datum for the survey: we usually refer to this as putting in "control". The actual technique used is not critical to the client, but it is important to establish if the "control" will lead to three-dimensional coordinated points or not. Some of the simpler "tape and level" methods do not. Coordinated points will give a better standard of accuracy overall, and allow horizontal and vertical cross-sections to be prepared.

Camera type

For the photogrammetric process, it is essential that a camera known as a "metric" camera is used. These cameras have distortion free lenses, and are specially constructed by the manufacturers of photogrammetric instruments. Once again, it will not generally be important to the client to know the exact make of camera used, although particularly where there are archival considerations, the truism, "the more square inches the better" holds. For rectified photography, a metric camera is not essential, but may be used.

Accuracy

The accuracy possible from the photogrammetric process can often be surprising to the layman. This is most vividly illustrated by reference to aerial survey: from photographs taken from 1500 feet (500 m), heights of points on the ground can be established to within 3 inches (7.5 cm). With the photogrammetric line drawing, we have no difficulty in obtaining accuracies in the order of + 1 to 1.5 centimeters (0.4 to 0.6 ins), at 1:50 scale. This is within the "line-width," and means that any measurements taken (on the polyester film version supplied) will be as accurate as you can scale them with an ordinary scale rule. However, the accuracy obtained is ultimately a function of the original photo scale: therefore, photography taken at average scales for a 1:50 plot, cannot simply be 'blown up' to obtain accuracies of 1 or 2 millimeters, as might be needed for a critical dimension such as the width of a window opening.

Working restrictions

One of the valuable assets of photogrammetry can also work against it. This "non-contact" method of recording by photography avoids scaffolding and is generally safer, but of course if there is any obstruction between the facade and the optimum taking point for the photography, difficulties will arise. If there are trees and vehicles in view some parts of the facade will be obscured. However, except in the most extreme cases, it is our experience that far more of a facade can be recorded than the client might expect. Choice of camera station, "oblique" photographs and aerial platforms can all overcome the problem of recording obscured areas.

Speed of production

This will obviously be an important factor to the client. While photogrammetric products are in general much quicker to produce than hand measured surveys of comparable accuracy and thoroughness, they cannot usually be produced overnight! As a rough guide, a day's fieldwork under average conditions could produce 8-12 stereomodels, plus "control" measurements. This would cover, say, the front and rear facade of a building with a street frontage of 30-40 meters (90-120 ft). Plotting is more difficult to define. If our example was of fairly plain London brick facade, plotting might be three to five days. If the same facade was of ashlar, and heavily ornamented, plotting time could go up, to ten to fifteen days. Field checking or completion could also add one or two days.

Submission

When commissioning work the client should discuss with the surveyor the amount of survey data to be handed over with the drawings. This may affect the overall cost of the work. For example, the client may wish to receive contact prints or photographic negatives of the record drawings or selective enlargements of particular surveys to enhance his data bank. Alternatively, he may wish to receive control data (interpreted rather than in a raw form) for archive purposes. Discussions should also be held on who is to hold the copyright of the survey.

(By Ross Dallas of the Photogrammetric Unit of the Institute of Advanced Architectural Studies of the University of York, and John Fidler of English Heritage)

APPENDIX 4

PLANNING TO PROTECT AN INSTITUTION AND ITS COLLECTIONS

Few libraries, museums, or historical societies have the prescience to develop a plan for the handling of a disaster--a disaster which may never come and which the odds indicate will happen to someone else. Unfortunately, institutions do suffer damage from fire, water, or extremes of nature, and when no plan for handling such emergencies is available, the loss will be greater than necessary. The following considerations may help in drafting a plan for specific situations.

Insure

Be certain that insurance coverage is complete and covers the collection, equipment and building--as well as office furniture, restoration of files, costs of temporary relocation, and the myriad expenses involved in returning to the status quo before the disaster.

The first step in planning is to locate an insurance agent who can help to provide the proper coverage for all aspects of the institution's activities and holdings. Advice can be sought from local insurance representatives or from the appropriate professional organizations such as The American Library Association, The American Association of Museums, The American Association of State and Local History, or other pertinent organizations.

Working with an insurance expert is essential, for few professionals in museum or library work know the intricacies of proper coverage. The kind of records needed to estimate damage or loss to prove a claim are most important if an adequate settlement is to be reached. The details on which claims might be based must be well documented: records of the date of acquisition, source, original cost, current replacement values, and so forth must be readily available, for there will be no time to develop such details after a disaster when the struggle to maintain services and to restore the collection must go on concurrently.

Insurance coverage should be considered not only in terms of replacement costs but in terms of restoration costs as well. A price can be set for replacing a standard dictionary, but what is the restoration cost or loss-of-value factor if a nineteenth-century pamphlet or unique Venetian goblet is damaged or destroyed? What is the value of staff time in replacing a damaged or destroyed catalogue of holdings or in reconstructing files and records?

Keep and duplicate appropriate records

The accession records, shelf list, or catalogue of collections are among the most important holdings of an institution, sometimes more important after a disaster than the items they represent. No proper inventory, no adequate claim of loss can be carried out without adequate and available data when catastrophes occur.

Such data should include a complete description of the object, with size, condition, etc., date of acquisition, source, provenance (where applicable), or original cost, current replacement value (this can be of assistance as well in adjusting insurance coverage as values increase or if de-accessioning of duplicates is under consideration), number of pages (books), number of plates illustrations (colour, black and white), and other pertinent information.

Not only must documentation be complete and up-to-date, but it must be available--which implies duplicate copies. A complete catalogue is of little help if the only copy is destroyed in the disaster. All key records should be available on microfilm and copies should be stored far away from the institution's headquarters so that they will not be lost also. Storage in a bank vault is not good enough--if the bank is in the same disaster-prone area as the institution. Duplicate records may be kept in the general area, but a master microfilm should be stored, preferably in a commercial archival storage vault where proper humidity control is available. Storage firms can usually produce duplicate copies of masters if such are needed. Information on such facilities can be obtained from the National Microfilm Association.

Once the records of all holdings have been microfilmed, an annual filming of new records should be undertaken to keep the records complete. Often this means keeping an additional accession card to be used for the filming at the end of the year. Periodically (every five or ten years) it would be well to re-microfilm the master records so as to provide one master duplicate file which can replace the original master microfilm and its five or ten supplements.

(By John H. Martin, ed., *The Corning Flood: Museum Under Water*, Corning, New York, The Corning Museum of Glass, 1977, p. 54)

APPENDIX 5

MODIFIED MERCALLI INTENSITY SCALE

I	Imperceptible	Not felt. Registered only by seismographs.
II	Very slight	Felt in upper storys solely by persons at rest.
III	Slight	Felt indoors. Vibrations like those caused by light trucks passing by.
IV	Moderate	Hanging objects swing. Vibrations like those caused by heavy trucks or a jolt such as that occasioned by a heavy object striking the wall. Parked cars are set in seesaw motion. Windows, doors, and crockery rattle.
V	Fairly strong	Felt outdoors. Sleeping persons wakened. Small objects not anchored are displaced or overturned. Doors open and close. Shutters and pictures are set in motion. Pendulum clocks stop and start or change their speed.
VI	Strong	Walking is difficult. Windows, crockery, and glass break. Knickknacks, books, etc., fall off shelves; pictures fall from the walls. Furniture moves or is overturned. Cracks in weak plaster and materials of construction type D. Small bells ring (church, school).
VII	Very strong	Noticed by car drivers, passengers. Material of construction type D sustains serious damage. In some cases, cracks in material of construction type C. Weak chimneys break at roof level. Plaster, loose bricks, stones, tiles, shelves collapse.
VIII	Destructive	Steering of cars made difficult. Very heavy damage to materials of construction type D

		and some damage to materials of type C. Partial collapse. Some damage to materials of type B. Stucco breaks away. Chimney, monuments, towers, and raised tanks collapse. Loose panel walls thrown out. Branches torn from trees. Changes in flow or temperature of springs. Changes in water level of wells. Cracks in moist ground and on steep slopes.
IX	Highly destructive	General panic. Material of construction type D completely destroyed. Serious damage to material of type C and frequent collapse. Serious damage also sustained by material of type B. Frame structures lifted from their foundations, or they collapse. Load-bearing members of reinforced concrete structures are cracked. Pipes laid below ground burst.Large cracks in the ground. In alluvial areas, water, sand, and mud ejected.
X	Extremely destructive	Most masonry and wood structures destroyed. Reinforced steel buildings and bridges seriously damaged, some destroyed. Severe damage to dams, dikes, and weirs. Large landslides. Water hurled onto the banks of canals, rivers, and lakes. Rails bent.
XI	Disaster	All structures collapse. Even large, well-constructed bridges are destroyed or severely damaged. Only a few buildings remain standing. Rails bent and thrown out of position. Underground wires and pipes break apart.
XII	Major disaster	Large-scale changes in the structure of the ground. Overground and subterranean streams and rivers changed in many ways. Waterfalls are created, lakes are dammed up or burst their banks. Rivers alter courses.

Construction type A

Good workmanship, mortar and design; reinforced, especially laterally, and bound together using steel, concrete, etc.; designed to resist lateral forces.

Construction type B

Good workmanship and mortar; reinforced but not designed to resist strong lateral forces.

Construction type C

Ordinary workmanship and mortar; no extreme weaknesses such as failing to tie in at corners, but neither reinforced nor designed to resist horizontal forces.

Construction type D

Weak materials such as adobe; poor mortar, low standards of workmanship; horizontally weak.

APPENDIX 6

FROM RESTORATION TO MAINTENANCE OF HISTORIC BUILDINGS

Good maintenance makes a historical building, an art object, a person and even a car beautiful provided it respects the patina of age and use, and provided the methodology cooperates with the nature of materials. It is a continuing process which was described by William Morris in the Manifesto of the Society for Protection of Ancient Buildings published in 1877 with poetic simplification as "stave off decay by daily care".

It is worth remembering that annual maintenance was as essential feature of vernacular architecture based on such sensitive materials as mud brick and plaster or thatch. Traditional maintenance practices such as lime washing or removal of paintwork and even lacquer on temples should be studied.

As Morris would have wished, we have moved from restoration to maintenance. Restoration involved major interventions with campaigns at widely spaced intervals which were expensive, often damaging, sometimes unjustified, but dramatic and sometimes attractive. They were inevitable followed by long periods of neglect. However, time, the fourth dimension in all conservation work, would show otherwise.

Maintenance is a process involving the minimum intervention at any one time, and it allows craft skills to be preserved by use, and craft training to be developed. If properly organized, it is far less expensive in the long run than neglect. The level of maintenance required varies because it is a combination of the standard required by the users of the building, the minimum requirements of the building itself, and the availability of finance. The building's requirements depend in the first place on the climate in which it is situated, and the agents of decay to which it is subjected, which are generally by-products of the climate, but also due to intrinsic causes such as the nature of the materials of which the building is constructed, and the quality of the original workmanship. Bad repairs and past alterations or events such as floods, fires and earthquakes can all affect the condition of the building, making it more sensitive. External changes such as increased traffic vibrations and atmospheric pollution also have a direct bearing on maintenance standards. It is worth noting that well maintained traditional buildings survived the 1979 Montenegro earthquake, whereas those that had received no maintenance collapsed when subjected to the same intensity of vibration.

How do we develop a strategy for preventive maintenance? What is against it? To answer the second question first, the development of strategic maintenance for historic buildings requires professionals of high skill and cultural preparation, who must be paid.

They save the building owner a lot of money in the long run, but in the short run, he only sees the cost of professional time, so he thinks it is expensive.

A strategy for preventative maintenance is based on inspections by properly training professionals, generally architects, carried out at regular intervals. The intervals and standard required depend on the climate, the construction of the building, and its environment.

It should be recognized that due to their longevity, historic buildings have to withstand greater hazards from wind and rain Because of their irreplaceable value, fire precautions and lightning protection must be given high priority.

There are interesting schemes for regular inspections of Churches in Denmark and of private historic buildings in Holland, but my own experience is based on twenty five years work on a large number of medieval Churches in Norfolk, England under the Inspection of Churches Measure 1955. In England, 18,000 Churches come under this scheme, which has been dramatically reduced the cost of maintenance to the minimum standard of wind and watertight. This standard should be interpreted in an intelligent but not too literal way. The success of this scheme is a confident answer to the first question - what can be against such a scheme if it saves money, and preserves historical buildings. The scheme has an additional use now that State subsidies are available to Parish Churches that qualify by conducting regular inspections at five year intervals,

The key to the whole success of the operation is the inspection by a competent person. To initiate the scheme, special short courses were arranged by the Institute for Advanced Architectural Studies in York, and now there are nearly 400 Architects and a few Surveyors with this specialist skill.

The time taken to make an inspection varies in accordance with the size and complexity of the building, a simple Church with two or three Chambers and Tower taking 5-6 hours, a large Church some 20-30 hours, and a great Cathedral like York Minster, for which I was responsible, 2,000 man hours. A Country House is like a large Church in general complexity, which a small house or shop can be inspected in four hours.

Proper equipment is needed to make the inspection. Paper, writing board, pencils, penknife and short crowbar are essential, to which you can add a mirror for looking behind things, screwdriver, hammers for tapping and special equipment such as moisture meters, hygrometers and metal detectors. A magnifying glass is also useful. I like to write all mu factual report on the site as this process makes me "see" and think, and if "seeing" raises questions, I can easily solve them by looking from a different position. One is like a detective seeking criminal causes of decay.

The report must describe the building, its layout and surroundings, and give a resume of its history. It is most important to identify all materials and clarify ones report with sketch plans and details. Then one lists the condition of all items methodically, working from the top to the bottom, and always clockwise round the building or a suitable section of the building. The inaccessible spaces and hidden places that cannot be inspected must be listed in the report.

Finally, one must propose a course of action and give approximate estimates. Estimating is difficult, but experience helps. Without estimates, the report is almost valueless. I suggest that one give two figures--a reasonable figure for the cost of the work and a top figure that takes every unknown difficulty into account. Estimates might be given in five general categories according to need: IMMEDIATE, URGENT, NECESSARY, DESIRABLE, and UNDER OBSERVATION.

These categories give a strategy for each building in which one must balance the correct sequence for building repairs, i.e., roofs first, with the urgency of the item. The basic strategy has been taken even further by Henry J. Chambers in his sophisticated report on Cyclical Maintenance of Buildings, in which he evaluates the required frequency of all maintenance operations, including daily cleaning. Regular inspections for each building can become a national strategy for maintenance of our cultural property. We should at least hand on our historic buildings and monuments to the next generation in a little better condition than they were in when we received them from our fathers.

APPENDIX 7

DAMAGE RECORDING SHEETS

(as developed by the Republic of Montenegro, Yugoslavia)

Damage Assessment Form

Immovable Cultural Property

1. Name of Monument

Reference Number

Century of Construction

2. ☐ Archaeological site
☐ Urban group of buildings
☐ Fortified urban area
☐ Monastery/monasteries
☐ Rural group of buildings
☐ Isolated monument

		12	13	14	15	16	17	18	19	20
Religous monument	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Habitation	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Public building	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Building serving an economic purpose	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Military architecture (fortified)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Ethnological structure	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Building serving a technical purpose	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Monument to the struggle for national liberation	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

3. Location

Community
Town
Place
Address
Land register no.
Owner

Overall Floor Space (m^2)

Basement
Ground floor
1
2
3
4
Total

Condition Before Earthquake
☐ Good
☐ Medium
☐ Poor

Category of Monument

Protection Agency

4. Damage Caused by the Earthquake

Destroyed	Heavily Damaged	Damaged	Slightly Damaged	Intact	
☐	☐	☐	☐	☐	Chimney(s)
☐	☐	☐	☐	☐	Covering
☐	☐	☐	☐	☐	Structure
☐	☐	☐	☐	☐	Dome(s)
☐	☐	☐	☐	☐	Vault(s)
☐	☐	☐	☐	☐	Ceiling(s)
☐	☐	☐	☐	☐	Wooden floor structure(s)
☐	☐	☐	☐	☐	Other floor(s)
☐	☐	☐	☐	☐	Bearing wall(s)
☐	☐	☐	☐	☐	Nonbearing wall(s)
☐	☐	☐	☐	☐	Arch(es)
☐	☐	☐	☐	☐	Column(s)
☐	☐	☐	☐	☐	Staircase(s)
☐	☐	☐	☐	☐	Foundations
☐	☐	☐	☐	☐	Belfry/belfries
☐	☐	☐	☐	☐	Minaret(s)
☐	☐	☐	☐	☐	Architectural decoration
☐	☐	☐	☐	☐	Iconostasis
☐	☐	☐	☐	☐	Mural painting(s)
☐	☐	☐	☐	☐	

5. Degree of Danger
☐ Repair feasible
☐ Repair impossible

Status of the Monument
☐ Unchanged
☐ Changed
☐ Not retained

☐ **EMERGENCY ACTION**

6. Outline Plan (at ground level) of the Monument and Principal Dimensions
Photographs and indication of damage
(attach plans)

7. Structural Characteristics

Type and quality of building materials and bonding components

8. Description of Deformations and Structural Damage

9. Emergency Action Proposed

- ☐ Total demolition
- ☐ Partial demolition
- ☐ Temporary covering
- ☐ Shoring
- ☐ External scaffolding
- ☐ Internal scaffolding
- ☐ Protection of mural paintings
- ☐ Protection of architectural decoration
- ☐ ______________________

10. Repair Program Proposed

☐ Demolition(s)	☐ Bearing wall(s)	☐ Belfry/belfries, minaret(s)
☐ Chimney(s)	☐ Nonbearing wall(s)	☐ External plastering
☐ Covering	☐ Arch(es)	☐ Internal Plastering
☐ Timber Structure	☐ Columns	☐ Preservation
☐ Dome(s)	☐ Piers	☐ Restoration
☐ Vault(s)	☐ Beam(s)	☐ ______________________
☐ Ceiling(s)	☐ Staircase(s)	☐ ______________________
☐ Wooden floor(s)	☐ Geomechanical exploration	☐ ______________________
☐ Other floor(s)	☐ Foundation(s)	☐ ______________________

11. Damage Classification and State of Usability of the Building

Defined by the Technical Commission for Damage Assessment in the Socialist Republic of Montenegro.

I. Usable (green)
- ☐ IA – grade 1 – intact except superficial damage
- ☐ IB – grade 2 – no structural damage
- ☐ IC – grade 3 – light structural damage

II. Temporarily unusable (yellow)
- ☐ IIA – grade 1 – structural damage
- ☐ IIB – grade 2 – heavy structural damage

III. Unusable (red)
- ☐ IIIA – grade 1 – very heavy structural damage
- ☐ IIIB – grade 2 – partial destruction
- ☐ IIIC – grade 3 – total collapse

12. Estimated Cost of Repair

1. Value of the building before the earthquake

_________ m^2 x _________ (cost) = _________ total cost

2. Cost of restoring the building to its pre-earthquake condition (structural repair)

_________ m^2 x _________ (cost) = _________ total cost

3. Total cost of repair (consolidation)

_________ m^2 x _________ (cost) = _________ total cost

13. Notes

Members of the Commission

Photographic Coverage

Number of Negatives

Photographer

Copyright Owner

Place

Date

Inventory of Damage

Damage Assessment Form

Movable Cultural Property

1. Name of Object

Reference Number

2. Nature of Object

Century of Construction

		12	13	14	15	16	17	18	19	20
Religous	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Profane	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Ethnological	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Archaeological	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Literary/archives	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Technical	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Object in the struggle for national liberation	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

3. Material

☐ Metal
☐ Wood
☐ Fabric/textile
☐ Leather
☐ Paper
☐ Pottery
☐ Glass
☐ Porcelain
☐ Stone
☐ Bone
☐ Horn
☐ Parchment
☐ Precious stones
☐ ____________
☐ ____________

4. Location

Community

Town

Place

Address

Owner

Condition Before Earthquake

☐ Good
☐ Medium
☐ Poor

Classification Category

Protection Agency

5. Damage Caused by the Earthquake

☐ Destroyed
☐ Heavily Damaged
☐ Damaged
☐ Slightly Damaged
☐ Intact

6. Degree of Danger

☐ Repair feasible
☐ Repair impossible

Status of the Object

☐ Unchanged
☐ Changed
☐ Not retained

☐ **EMERGENCY ACTION**

7. Drawing of the Object and Principal Dimensions

Photographs and indication of damage (attach drawings and photographs)

8. Principal Characteristics of the Object

9. Description of Deformations and Damage

10. Emergency Action Proposed

- ☐ Cleaning
- ☐ Dismantling
- ☐ Packing
- ☐ Transport
- ☐ Disinfection
- ☐ Storage
- ☐ Drying
- ☐ Inventory
- ☐ Photographs
- ☐ ______________________

11. Repair Program Proposed

- ☐ Total preservation
- ☐ Preservation with reconstitution
- ☐ Preservation with restoration
- ☐ ______________________
- ☐ ______________________

12. Damage Classification and State of Serviceability of the Object

- ☐ Serviceable
- ☐ Temporarily unserviceable
- ☐ Unserviceable

13. Estimated Cost of Repair

Cost of restoring the object to its previous condition ______________________

14. Notes

Members of the Commission

Photographic Coverage

Number of Negatives

Photographer

Copyright Owner

Place

Date

APPENDIX 8

STRUCTURAL INTERVENTIONS IN HISTORIC BUILDINGS

Experienced engineers and architects met together at ICCROM in Rome, to discuss an appropriate technology for the conservation of historic buildings. The members of the workshop were P. Beckman (Denmark), B.M. Feilden (ICCROM), J. Heyman (U.K.), M. Kolaric (Jugoslavia), R.W. Mainstone (U.K.), G. Musumeci (Italy), W. Preiss (D.D.R.), P. Sanpaolesi (Italy), E. Schulze (F.D.R.), G. Tampone (Italy).

Their ideas are summarized below. To some, these may seem revolutionary, to some reactionary, and to some the obvious lessons of history.

The official "Code of Practice" approach to historic buildings is virtually rejected. The functional value of traditional materials such as lime mortar, is recognized again, and the Venice Charter reaffirmed.

While not rejecting modern techniques of analysis, the value of careful observation and appraisal for training architects and engineers in the appreciation of the structural behavior of historic buildings--thus encouraging a qualitative intuitive understanding--was emphasized as the appropriate design technology. After all, it was the technique the masons used in the past to build their breathtaking masterpieces.

Historic buildings as structures: forms, observation, analysis, and diagnosis of weaknesses

Several broad classifications of the structural forms used in the past and of characteristic responses to wind, weather, earth movements, and the ever present action of gravity are possible. They are a helpful, perhaps even necessary, starting point for appreciating the condition of a particular building. But it must be emphasized that each building is an individual and, like an individual human patient, must be so considered by the "doctor architect" or "doctor engineer." As with the human patient its past history is important, and also its environment. Above all, the historic building, must also be considered as a whole, which might mean paying as much attention to the ground beneath as to the visible superstructure.

Detailed measurements and analyses should be guided by the qualitative picture gradually built up from direct visual observation and study of the past history through documents, etc. Drawings with overlays, or even simple models, are a useful means of concretizing this picture. Standard notations for cracks, displacements, etc., are also helpful. Much can, in fact, be achieved by such observation alone and by the visualization, based upon it, of the possible modes of collapse. Detailed measurements and calculations are valuable in giving quantitative precision where it would otherwise be lacking and in distinguishing between alternative possibilities.

Measurements of deformations to an accuracy of + 3 to 5 mm is considered adequate for most preliminary observation, but much greater accuracy is called for in long-term monitoring of possible increases or of the effects of interventions. A firm datum is required and measurements should be made at frequent and regular intervals. They should be plotted as made and regularly reviewed. Out-of-plumb deformations are not easy to measure. The use of plumb bobs is costly in labor, subject to interference by wind and weather externally, and calls for damping if reasonable accuracy is to be attained. Optical plumb bobs and precision clinometers also have practical limitations. The correlation of inclinations from the vertical, particularly if carried out in association with a study of other related deformations including changes in level is, however, a possible fruitful means of elucidating the structural history of a building where other evidence is lacking or equivocal.

In carrying out analyses of the structural condition, the most appropriate technique must be selected for each case in light of all observations made and questions posed. The problem as a whole and the inevitable limitations of the analysis must never be lost from sight. Techniques ranging from simple thrust-line graphic analyses of arched systems to computerized finite-element analyses all have their parts to play, though little role was seen for the costly and often unrealistic photoelastic experimental technique. Above all the "Code of Practice" approach has been found to be irrelevant, not only because the structures of historic buildings differ considerably from those envisaged by current codes, but also because historic buildings are structures that already have particular weaknesses. For the same reason, though with slightly less force, current design criteria and procedures are unlikely to be directly relevant. The "moment of decision" is essentially one for the exercise of the responsible engineer's or architect's own judgment, supported, if need be, by that of his peers. A reminder that present overall stability is never a sufficient guarantee of future stability was provided by a recent partial collapse of the Ospizio di San Michele, Rome. On 31 March 1977 it was declared unsafe and evacuated as signs of distress were noted, and about twelve hours later it collapsed, partly as a result of the thermal shock of a particularly cold night.

Below-ground interventions

With uniform loading on ground that offers uniform support, a building should settle uniformly even if the loading is excessive by modern standards. It thus forms its own foundations. In the case of a historic building such settlement will usually have taken place long ago and now matters little. Even a linearly varying settlement, as a result, perhaps, of a continuous variation over the length or breadth in the support conditions, matters little if the resulting bodily tilt of the building is not excessive in itself or in relation to its height. Differential settlements of a nonlinear kind, such as a greater settlement in the center of a building, are the ones that matter most, since they can be absorbed only by weakening deformations of the superstructure. Observations of comparable structures may help in assessing how much differential settlement a building can accept, though it must be remembered that this tolerance is partly dependent on the original speed and sequence of construction. With a slow building program in which construction is carried up fairly uniformly over the whole extent of the building, much of the initial settlement is accommodated without structural deformation by built-in changes of level, as occurred with St. Paul's Cathedral, London. In such cases, settlement histories can, and should, be constructed, as has been done for the Campanile in Pisa and for York Minster in London.

Usually conditions below ground remain virtually unchanged through the centuries while the structure above ground suffers a progressive loss of strength due to weathering and decay of materials and the disruptive effects of cyclic temperature changes, etc., interrupted from time to time by human interventions. This situation should not, however, be taken for granted. Water levels in particular may change as a result of drainage, pumping, obstruction of underground flows. Other interventions and conditions may also be changed by adjacent works of other kinds. The effects of a change in the water table may be difficult to predict, but is usually undesirable. Preservation of the water table is therefore usually important. It was, for instance, reported that two thirds of the present increase in the lean of the Campanile in Pisa was due to water abstraction and that the earlier water table was now being reinstated by pumping in water. Local de-watering or pumping constitutes a similar danger, particularly if it leads to the removal of silt, Where differential settlement is leading to excessive deformations of the superstructure, the situation should be analyzed in both its above-ground and below-ground aspects. The relative merits and costs of strengthening the superstructure, underpinning it (i.e., carrying the foundationdown to an existing firmer stratum), and improving the soil conditions should then be weighed against one another to select the best course of action. Possible methods of improving the soil condition (each with the advantage of leaving the historic building untouched) include: (1) weighing the surroundings to prevent adjacent uplift, (2) local water extraction to cause local shrinkage and thereby a corrective differential settlement, or (3) drainage or de-watering.

Adoption of these methods call, however, for thorough prior investigation and careful skilled control. It is also possible to stabilize the soil through high-pressure injection but this requires special technology, expensive plants and is difficult in built-up areas. In all cases of possible hazard from ground movement, it is desirable to investigate the general geological background in order to locate and identify the particular hazard which may, for instance, be a geological fault line or the presence of fine laminations in a clay soil.

Above-ground interventions

Thermal movement and movements due to changes in moisture content must be reviewed. Severe cracking can occur, also, as a consequence of fire or the introduction of central heating. Because, even in the absence of extreme events, such as a serious fire, some cyclic movements continue to take place, it is useless to attempt to eliminate all cracking from historic buildings. Necessary reinforcement should be designed simply to keep it under control. Materials must be considered both in relation to structural consolidation and weather protection of masonry structures. In relation to the latter, Swedish data emphasize, in particular, the great merits of traditional, elastic, relatively absorbent, and easily renewed lime mortars for pointing and rendering. Cement mortars are, on the other hand, stiffer, almost impermeable, and excessively strong. It must be recognized though, that climatic conditions vary greatly and that the role of an external wall as weather skin and environmental filter likewise vary. The correct choice of materials in any particular case must be made in terms of the local conditions, and considering the total function of the wall (which might, for instance, have an important fresco on the other face), the existing construction and materials and the available materials and skills.

In any wall or pier it is desirable that the core should be as strong and stiff as the facings and should be well bonded to them. Except in some solid brick walls, a few walls of pure ashlar masonry, and most Roman concrete walls, this is rarely found to be the case. Short of completely reconstructing walls and piers with weak rubble cores and the like, grouting is the only available technique of consolidation, possibly assisted by the introduction of a limited amount of reinforcement.

Stronger mortars are then desirable, though cement mortar again can be criticized on the grounds of excessive hardness, lack of elasticity, and impermeability. This topic needs full discussion with builders and engineers.

Conclusions and recommendations

1. Before starting an investigation undertake any major intervention, the engineer and architect should have a clear idea of the objective. What are the important characteristics of the buildings? Which buildings are most desirable to conserve, and for what future use? Continued "use" in the normal sense of the word is always preferable to mere preservation as a monument, museum, or simply part of the scenery, since it enables the building to continue to play a full social role and provides the best guarantee of continued attention and proper maintenance care. But there are also buildings or remnants of buildings with an important future

use as physical embodiments of past cultures or examples of supreme past achievements which must be conserved.

2. Whatever the objectives, each historic building presents unique problems. It is an individual structure and its needs should be individually assessed, while keeping a proper sense of proportion about the justifiable depth of investigation.
3. Investigation of the building's needs should take into account all relevant facts including not only future use, but also environmental conditions, foundation conditions, and its past history. This last could be very important in correctly interpreting apparent signs of distress; usually the present condition of the structure should provide some clues, but documentary sources should also be consulted.
4. A qualitative structural assessment should usually precede and guide quantitative analyses that may otherwise be based on mistaken assumptions or misleadingly concentrate on the more obvious aspects of the problem to the neglect of the real total situation. Analyses should also start from first principles and not attempt to take short cuts by using rules from current "Codes of Practice" or other current design procedures, since these are never truly applicable to historic buildings and if applied may cause damage.
5. Where remedial interventions are considered to be necessary they should respect, as far as possible, the character and integrity of the original structure. They should, as far as possible, use similar materials. Where different materials are substituted, care must be taken not to introduce elements of excessive strength or stiffness into a structure that will usually be less stiff and more accommodating to long-term movements than contemporary structures.
6. The final choice of the approach to be adapted should be made only after a proper appraisal (consistent with the scale of operations and the resources available) of alternatives and with some eye to the future. In general, interventions that can be undertaken in stages, that can be controlled by monitoring their effects, and that can be repeated, reinforced or reversed as necessary are preferable to those that are irreversible, and call for a complete advance commitment to a single course of action. All that is done should be fully recorded future reference.
7. The best further safeguard for the future is to place the building under the continuous care of someone like a "Dom Baumeister" or a "Cathedral Surveyor," preferably assisted by a permanent small staff of skilled craftsmen who learn to know the structure intimately.
8. Because of the very limited relevance of current design procedures to the conservation of historic buildings,there should be more training of architects and engineers in an appreciation of the structural behavior of such buildings.

APPENDIX 9

International Course on Preventive Measures for the Protection of Cultural Property in Earthquake Prone Regions

Skopje, Yugoslavia; June 24-July 5, 1985

FINAL RECOMMENDATIONS

Expecting that progress in such studies will continue and that more special interdisciplinary studies on historic buildings be undertaken so that the "state of the art" will improve,

Appreciating that every historic building is unique and deserves special studies, it is recommended

1. that the structural system of such historic buildings should be respected because it may have already resisted a number of earthquakes,
2. that any new materials and structures used for repair and strengthening should be compatible and durable and that the use of reinforced concrete be restricted,
3. that the degree of protection required should be assessed individually based on the various probabilities of seismic events and the possibility of further strengthening at a future date when better techniques will have been developed,
4. that the loss of cultural values should be assessed for different seismic effects involving the formal consideration of alternative projects by engineers, historical architects, archaeologists and art historians,
5. that building owners or occupiers be encouraged and instructed to better maintain the existing structural system and fabric,
6. that a thorough documentation and survey of historic buildings in seismic areas be undertaken and a schedule of regular inspections and maintenance be organized,
7. that a microzoning study of seismic risk be undertaken starting with the most vulnerable historic building sites.

Further it is recommended

1. that experimental and analytical research on the earthquake resistance of masonry and masonry structures be increased with special emphasis on historic building techniques and involving the study of ancient concepts of construction and antiseismic protection,
2. that research and testing of alternative grout mixes and evaluation of their long-term environmental effect on masonry will be initiated and that mortar mixes that are compatible with the nature of historic buildings be studied,
3. that the effectiveness of reinforcement techniques be evaluated from the actual behaviour of strengthened buildings in earthquakes.

APPENDIX 10

International Workshop on Structural and Functional Rehabilitation of Housing in Historic Buildings in Seismic Regions

Mexico City, August 25 - September 12, 1986

CONCLUSIONS AND RECOMMENDATIONS

Definition of problems:

The problems of the deterioration of housing in historic areas in seismic zones include the following:

1. On the political/administrative level:

   a. A global preventive policy for the mitigation of seismic risks in emergency situations, on a short-, medium- or long-term basis, does not exist or is not applied.

   b. As a consequence the socioeconomic measures taken, both during the emergency and on a medium- or long-term basis, are inadequate and often dangerous to the cultural heritage.

   c. An adequate conservation policy is generally not integrated in development plans.

2. On the social/economic level:

   a. The population struck by catastrophe is subject to eviction from its housing.

   b. In case of disaster, speculative tendencies and the pressure of economic interests on the urban land and housing become more acute.

   c. The progressive loss of the values that constitute the cultural identity is accentuated as a consequence of the socioeconomic management of the emergency situation.

   d. The social cohesion of the population in relation to its historic heritage is weakened.

3. On the physical/spacial level:

   a. The permanent seismic risk to which the urban settlements are submitted is increased by an accelerated process of urbanization.

b. The urban environment and architecture is affected by a deterioration process mainly caused by poor maintenance, as a consequence--among other factors--of the mechanisms that determine the relationship between tenants and owners. An earthquake causes a sudden increase of this deterioration and exposes all previously existing problems.

c. Intensive occupation of the dwelling spaces generates overcrowding and irregular rehabilitation.

4. On the technical level:

a. Technical knowledge about the behaviour of materials and structures of historic buildings under normal conditions and in earthquakes is still very poor.

b. Knowledge about the scientific bases that determine the seismic risk is also insufficient and is not diffused or applied.

General objectives:

To consider together the solution of three problems: housing in town centres, conservation of cultural property, mitigation of seismic risk, and to incorporate them in a long-term prevention policy.

To promote political incentives for a comprehensive vision and solution of these problems.

Recommendations:

Considering these problems and objectives, the following actions are recommended:

1. On the political/administrative level:

a. Incorporation of historic areas in national, regional and urban development plans, taking into account specific actions for emergency situations.

b. Establishment of a permanent conservation programme for these historic areas (maintenance and rehabilitation).

2. On the social/economic level:

a. Formation of a committee for protection and surveillance of historic areas and their population. The committee will have a mixed composition (representatives from neighbourhood organizations, professional corporations, governmental services) and will coordinate and supervise the actions for the safeguard of these areas on a permanent basis as well as in emergencies. The operation of this committee must be incorporated in the emergency programmes of the civil and governmental relief organizations (civil defence, army, Red Cross, etc.).

b. Promotion of programmes for defence of the sociocultural values of these areas, by means of networks of organizations on the neighbourhood and city-district levels.

c. Promotion among the population of knowledge about the permanent seismic risk to which it is exposed, oriented towards the development of measures and actions for mitigation of damage to the buildings and their inhabitants.

3. On the technical level:

   a. Promotion and diffusion of detailed information about the built heritage in seismic areas by means of inventories that describe the cultural values as well as the degree of vulnerability to earthquakes.

   b. Intensification of the training of technical and specialized personnel to cope with the problems of historic areas located in seismic zones.

   c. Systematic verification of the effect of the application of modern building technologies to buildings with traditional materials and systems, especially concerning behaviour in earthquakes, and the establishment of a permanent exchange agreement for investigations and experiences.

4. On the juridical level:

   a. Building codes that include adequate criteria for historic buildings and areas, and not only for new construction.

   b. Regulations for a better occupation and use of urban land, especially in historic areas.

   c. Codes that regulate ownership in historic areas and that ensure its preservation.

5. On the financial level:

   a. Formation of a permanent national fund for the study, conservation and revitalization of historic and traditional areas, giving precedence not only to the important monuments, but also to their architectural and traditional urban context.

   b. Channeling of social interest funds for application to the conservation and revitalization of housing in historic areas.

   c. Fiscal facilitation for projects for the conservation and revitalization of the built heritage.

   d. In the case of seismic emergencies, international economic supports that are destined for the revitalization of affected historic and traditional areas should be coordinated between the donating institutions or nations and the local authorities, with an adequate supervision that guarantees the accomplishment of the proposed aims.

APPENDIX 11

SOIL CONDITIONS: MICROZONATION

> Sites underlain by Holocene and Pleistocene sedimentary deposits undergo shaking 2.6 to 3.4 times greater than those underlain by crystalline rock for all period bands. The void ratio has a strong influence on short-period response, with void ratios in the 0.8-0.9 range indicating a mean response on soil 6 times greater than on crystalline rock and 3 times greater than on low-void-ratio soils. Amplitudes in the long-period band generally increase with increasing thickness of Quaternary and/or depth to basement.
>
> Parameters such as silt-clay, saturation, and depth-to-water table have been reported to influence site response, while shear velocity (or void ratio, which strongly influences the shear modulus), Holocene thickness, Quaternary thickness and depth-to-basement are all parameters that might be used directly in a model of site response. Most of these data are obtainable from geologic maps, well logs, and city files containing engineering boreholes for construction projects.
>
> For instance maximum amplitudes of motion recorded on the alluvial sites are several times larger than those recorded on the sedimentary or other crystalline rock sites. The degree of amplification occurring in the long-period peak amplitudes of these records is greatest at sites underlain by the thickest sediments.
>
> It should be noted that high short-period response may also occur at sites underlain by rock, if these sites are near the crest of a ridge or other pronounced topography (Rogers, Tinsley, and Hays 1985:5,7,13).

The seismic spectrum which describes the vibration intensities of different frequencies for a particular site will vary with local ground conditions, such as soil types especially those liable to liquefaction, the slope of sedimentary soils, the existence of any bedding planes and their angle of slope, faults, horizontal changes in soil types, the depths of soil over bed rock and the topography of bedrock including ridges and deposited soils. Water content and a water table less than 8 meters depth there is a danger of soil liquefaction in an earthquake.

Buildings with foundations on two different types of soil or those straddling a fault are particularly vulnerable. Risk zones should be mapped for historic buildings of different types. From these studies it is clear that to apply standard treatments to historic buildings does not make sound sense. Each building is an individual and each site has special problems which can only be resolved by a detailed study.

This kind of study on an area such as a town is called microzonation. Geologists and engineers can obtain general indications by observing the damages after a strong earthquake eventually. But normally a microzonation requires accurate geologic and engineering studies and examinations. A map at scale 1/5000 or 1/1000 can then be produced, indicating distinct sites with their seismic characteristics. Such microzonation is evidently of immense importance for the design of new buildings, but is also an indispensable tool for estimating the risk to existing structures.

EMERGENCY PREPARATIONS

As earthquakes do not happen often, this greatly complicates the task of advance preparation: even in an area of high seismicity it is hardly possible to set up special emergency squads and ask them to stand by, helmet on head, for an earthquake which may not come until the next century.

But it may equally well come tomorrow. At the level of a local or regional conservation service, such measures as can be takes should be designed to improve its capacity to act quickly during the critical period and to function independently while cut off from outside resources, particularly as telephones, services and electricity are likely to be cut off.

1. Electricity. Since the electricity is often cut off after an earthquake, the Administration should have an independent source of supply on the premises: a petrol-driven portable generator with a capacity of some 2.5 kW at 220 V and 50 Hz, both to light the premises (evening work will be needed for the first few days, because the hours of daylight will be spent in the field and to run the appliances: photocopier, photographic laboratory to develop and print the negatives brought back by the inspection teams, etc. There should also be two 50-meter reels of wire and a stock of good-quality connections (plugs, adapters, extension leads, etc.)
2. Fire. Earthquakes are often followed by fires, because they cause electrical short-circuits, burst gas pipes and the collapse of buildings around naked flames (stoves, heaters, etc.). Such fires may very well quickly reach enormous proportions (San Francisco 1906, Tokyo 1923) because it is often impossible to fight them: too many fires breaking out simultaneously, water mains cut, street traffic blocked by ruins and so on. Specific arrangements should therefore be made to provide both the premises of the Administration and every monument, according to its vulnerability, with a separate set of equipment - a powder type fire extinguisher, a stock of sand, and a petrol-driven water pump if there is permanent water nearby - and to train guards and all staff.
3. Vehicles. During the emergency it is vital to have vehicles (motor cycles, cars and vans) available in order to inspect monuments, evacuate moveable property, assess damage, organize emergency measures, etc. Hence the Administration cannot afford to allow either its own vehicles or the private cars of the staff (which

will be frequently pressed into service in such circumstances) to be put out of action by the earthquake.

Garage and car-park sites should therefore be chosen with care. In an earthquake area, garages made of light material (metal, wood, asbestos cement, etc.) on a flexible but wind-braced wooden or metal frame will always be preferred to masonry garages. Particular care should be taken not to park under several stories of offices or apartments. Even temporary parking of vehicles should be prohibited near buildings (within a distance equal to twice the height of the buildings), and not merely prohibited by signs but physically obstructed by planting trees, terracing, erecting low walls, digging ditches, etc.

In the San Fernando earthquake (USA, 9 February 1971), the reinforced concrete roof of the ambulance park at Olive View Hospital caved in on the vehicles. There is no need to emphasize how necessary ambulances are after an earthquake -particularly since in this case the hospital, badly damaged, had to be evacuated and the collapse of the electricity generating set had cut off the telephone and radio communications. In a disaster, its cars are, on balance, as important to the Administration as ambulances to a hospital.

4. Motor fuel. Supplies of motor fuel may also be cut off for several days. It is therefore advisable to keep a small reserve stock of fuel for vehicles and the generator (one or two 200-liter barrels of petrol and, if necessary, diesel oil) in a place which is isolated (an independent shelter) but proof against theft. A small hand-pump, or at least a flexible tube, should be kept in the same place to fill the fuel-tanks.
5. Advance preparations. Little in the way of direct preparations can be made in advance. It is, of course, simple enough to print damage assessment forms, to have a reserve stock of angle plates made and to buy steel rods for strapping, but what are the chances of finding these items quickly and in good condition if an earthquake occurs 50 or 100 years later? Such preparations are probably better organized on a national scale: e.g. the printing of stickers for marking monuments, which may be sent to each local or regional Administration and replaced every ten years (with the advantage of reminding officials of the earthquake threat); the printing of various forms and the stocking of materials and other items that can be sent to the disaster area as soon as an earthquake is reported.

   At local Administration level, rather than keep a stock of material lying idle which may be found at any time to have become unusable, or which may be ruined by the earthquake, it makes better sense to have supplies delivered regularly so that there is always enough in stock for the critical period. For example, in addition to the items mentioned above (paras. 2, 3 and 4), films, paper and photographic supplies, batteries for the torches and appliances (calculators, cameras, etc.), office supplies and drawing materials should be continuously available. But it would be a mistake to keep these supplies in a cupboard marked "Open only in case of earthquake."

The stock should be turned over regularly so that products such as films and sensitized paper do not become outdated. About one year's normal supply should be kept in stock; this may be used up in two or three weeks if an earthquake occurs.

(By Pierre Pichard 1984:37-38)

APPENDIX 13

RESOLUTION ON CULTURAL PROPERTY IN SEISMIC ZONES

ICCROM

It is recommended that each State Party with some of its cultural patrimony in seismic zones should:

1. Inform local administrators of their responsibility to establish emergency plans, with particular reference to the cultural heritage

2. Encourage cooperation between the service responsible for caring for the cultural patrimony and the local administration and military leading to emergency rehearsals at regular periods of years

3. Establish a national coordinator for rescue of cultural patrimony after a seismic event as a personal appointment in any national organization dealing with disaster relief

4. Give the name of such coordinators to the Secretariat of ICCROM

5. Authorize ICCROM to organize an international symposium for the appointed coordinators

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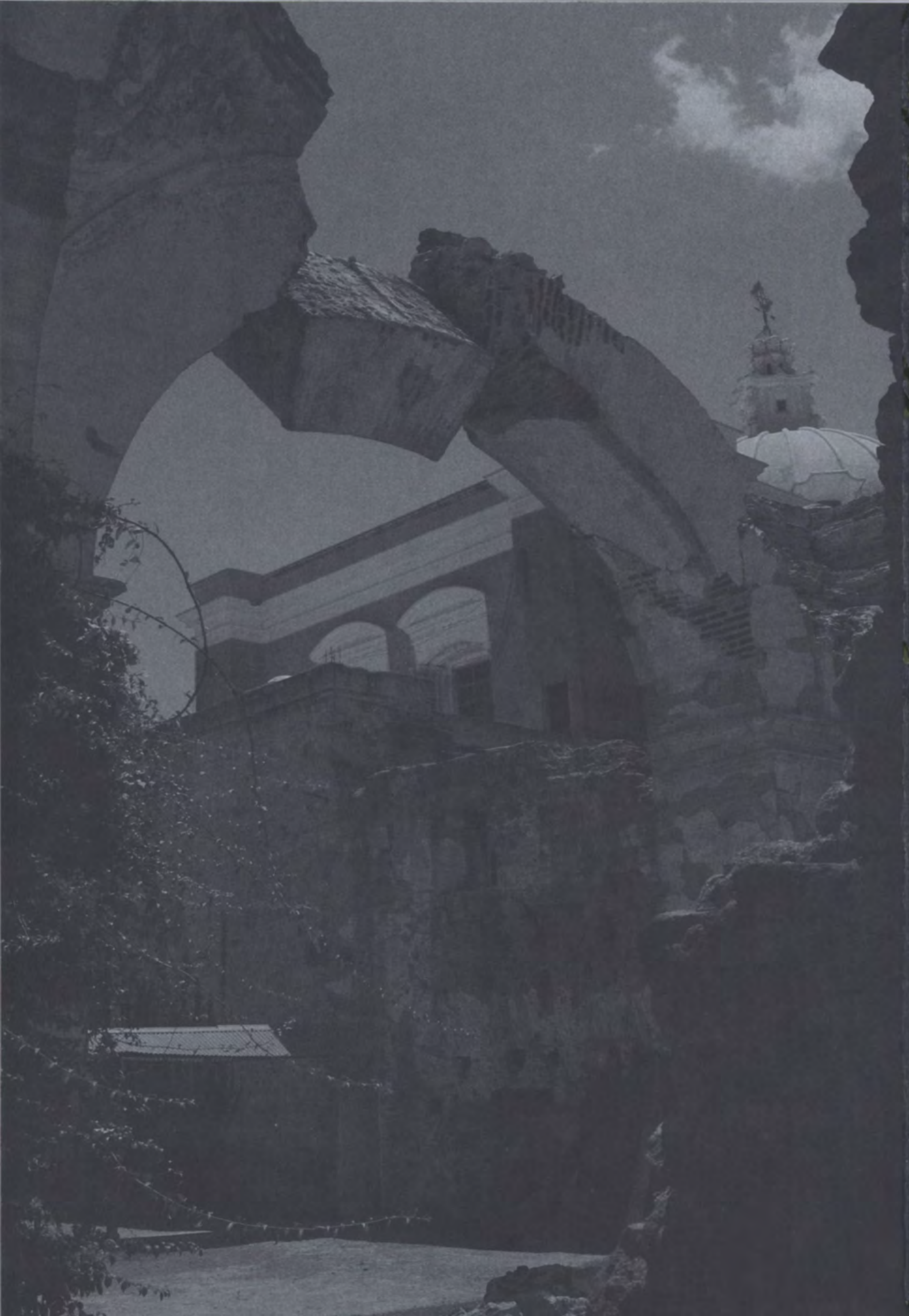

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