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CONSERVATION OF MATERIALS AND PRACTICAL APPLICATIONS OF SCIENTIFIC RESEARCH IN RESTORATION WORK

GENERAL REPORT

This paper is a general review of the problems of conservation of materials and stresses the need of understanding traditional techniques before making modern substitutes. The papers submitted by authors in this section are reviewed.

Causes of decay are considered briefly. The problems of craftsmen is touched upon. Comments are made on the general problem of atmospheric pollution and the universal but localized problems of vibrations. Regular inspections and a strategy for preventive maintenance of historic buildings is recommended in order to reduce decay and save money.

Studies of the internal environment and external environment are recommended in order to diagnose causes of decay correctly and the state of research relating to stone, wood and earth building is reviewed. Six suggestions are made as follows:

1) Every country should record its traditional crafts and take steps to maintain living knowledge of ancient skills and technology.

2) Histories of the technology of the Pre Colombian Americas and of East Asian countries are requested from UNESCO to assist conservation studies in the regions.

3) ICOMOS National Committees to be asked to provide more information on the typical causes of decay of buildings in their countries with particular reference, e.g. entomological causes, atmospheric pollution and acidity of rain.

4) Research into reduction of atmospheric pollution from small and medium sized heating plants should be initiated in a UNESCO programme.

5) Research into the problems of historic buildings and cumulative damage from traffic vibration to establish suitable standards is requested from governments under co-ordination by UNESCO.

6) Investigations into the effectiveness of earlier techniques of stone and wood preservation should be carried out by National Committees of ICOMOS.

Introduction

We must consider both materials for conservation and the conservation of materials. The paper *Traditional Materials and Environmental Constant* by Mrs. Tatiana Kirova shows the vital importance of indigenous materials in framing planning and conservation policies. The present economic system based on cheap energy and therefore cheap transportation has made the aesthetics of the architectural environment much more difficult, requiring that architects make conscious efforts to achieve a harmony that happened in the past almost automatically. The cost of quarrying stone in medieval times was one quarter of the total of delivered stone; now it is three quarters, because transportation is so cheap. Linked to these problems of the production of traditional materials are the problems of traditional craftsmanship. We have the examples of each of these questions from Scandinavia. Kristen Tollster of Sweden has presented a valuable paper on *Shingles and Shingled Roofs*, while Panu Kaila of Finland describes the history and production of wood tar and a revival of the technique in his paper *The Production of Pit Burnt Tar*.

It is interesting to consider this case. The original techniques were undoubtedly wasteful of natural resources. The forests were consumed, just as the Greeks and Romans consumed their natural resources faster than nature could recuperate, just as trees disappeared from the Middle East by consumption (although Tamerlane was conveniently blamed for cutting them all down) and just as we are now consuming the equatorial forests and destroying forever about three thousand species of plant life a year. We cannot go on at this rate, so conservation must take the use of both energy and nature's resources into account. Science is our main hope in solving this problem, but totally insufficient resources have been allocated to analysing why traditional materials and techniques often perform better than modern ones. The case in point is that Pit Burnt Tar has better qualities for

wood preservation than distilled wood tar and much better than tar distilled from coal. Why is this so?

Pit Burnt Tar is a vital material for conservation of wood, especially wooden roofs. Maintenance is a neglected science, but I suggest that preventive maintenance is the highest form of conservation, because it involves the minimum intervention. So here we have a contradiction to resolve; we need Pit Burnt Tar, yet we regret the wastage of trees and forests. Can science solve this problem? Or will economists say that it is of such a small scale that it is not commercially viable? There are certainly similar problems of much greater scale that do matter.

Craftsmanship and Technology

Linked to the use of traditional materials for conservation we have the problems of craftsmanship, which are certainly acute in industrialized countries and were recently discussed at Fulda under the auspices of the Council of Europe. The Council has set up a school in Venice for advanced training of craftsmen who already have basic skills and persons interested in this matter should contact the Director, Arch. Wolf Elbert at Isola San Servolo, Venice.

Important questions of workmanship and its effect on the durability of stone are discussed by G. Tampone and his colleagues.

Some lucky countries have plenty of craftsmen with a knowledge of traditional techniques and one wise country, Japan, included conservation of crafts in their legislation as early as 1929. Unfortunately, no papers on this specific topic were submitted, however, it must be said that the problems of conservation of bricks is inseparable from bricklayers, of masonry from masons and of carpentry from carpenters. Each trade gets its name from the material used. Nowadays we cannot expect the extreme specialization in craft skills which was obtained in the pre-industrial period, so we have to broaden the basis of knowledge of the craftsman to make him flexible and adaptable. We must respect his skill and teach him the principles of conservation and make him proud of the history of his craft, but above all he must love and respect historic buildings and not destroy documentary evidence and remove patina through his desire to make them as good as new. From a building craftsman he must be transformed into a conservation craftsman.

Can a skilled craftsman damage a historic building? I am afraid the answer is yes, if he does not understand the principles of conservation.

The ancient craftsmen were the technologists in the pre-industrial era and learned a great deal from centuries of trial and error, using acute observation to analyse causes and so to guide corrective action. There is much we can learn from ancient skills and technology. However, craftsmen are suspicious of inquisitive scientists and do not want to give away their secrets, as they are afraid that they will be supplanted, yet the secrets of ancient techniques must be analysed and understood if we are to use modern techniques in their place.

Before it is too late, every country should record its traditional crafts in the way that Hans Wulff did for Iran. This record is the basis of the history of technology, which is the really meaningful history of the world. We have an Oxford History of the Technology of the Western World and the Cambridge History of Chinese Technology, but we need also the technological history of the pre-Colombian Americas and that of Eastern countries. There is much ancient wisdom that has to be relearned.

Causes of Decay

Now let us look at materials themselves. They are subject to many causes of decay which the diagram summarizes. The causes are both due to the external environment and the internal environment of the building. Some are caused by the way it was built or from its materials. Understanding the phasing of construction work with ability to assess the quality of the original workmanship are vital factors in making a professional judgment on the condition of a building.

The function of architecture may be said to be the modification of climate in order to enable man to pursue his domestic, social, spiritual, cultural and economical activities; indeed, architecture enables man to become human. Building materials play a vital part in achieving this function of architecture, for example, in arid climates with extremes of temperature you get buildings of heavy materials with high thermal capacity, which evens out the extremes; while, on the other hand, in climates with high humidity you get light open structures to encourage air movement. Indigenous architecture teaches us that building techniques and the way materials are used respond to climate. The climatic data available to contemporary architects is generally rather inadequate, so instead of using the materials of their structures to help them solve environmental problems, they have handed over the problem to services engineers who use mechanical plant and energy to rectify the problems caused by lack of understanding of

how materials contribute to the " spatial environmental system " that is a building. The design of museums brings these fundamental problems into the foreground.

The paper on the Renwich Gallery, Washington, D.C., describes the climatic environmental stress to which one particular building is subject and comments that there are large and variable gradients in moisture and temperature between the inner and outer building shell and that the exterior material of stone and brick experiences substantial thermal and humidity variations, which lead to the decay of the sandstone decorative facings.

Depending upon the external climate we have biological, botanical and entomological causes of decay to consider. We are unfortunately rather ignorant about the relative impact of these causes in various climates, particularly in the case of entomological causes. However, it seems that termites are becoming increasingly aggressive. Unfortunately, no papers have been submitted on any of these matters.

The climatic data and the conservation of materials are problems that ICOMOS is in a unique position to study, using the resources of all its national committees.

Pollution

No papers have been presented on man made causes of decay, principally atmospheric pollution and vibrations. The former is a subject which ICOMOS should monitor, because it is essentially an international problem. For example a smoke plume from Britain can be identified in Sweden. Industrial pollution probably has many effects of which we are not aware, however, the effect on the salmon of Scandinavia and the growth of trees in the same region is well documented and arouses alarm. Industrial pollution increases the pH value of rain and each degree on the scale is ten times more potent than the last. Pollution is at least one hundred times worse in the industrial zones of eastern U.S.A. than in the Rocky Mountains.

In some laboratory tests it was found that the rate of decay of stone due to industrial pollution increases in proportions to something more than the square of the amount of sulphur dioxide in the air. This means that even a small reduction is beneficial, while a small increase is damaging. ICOMOS must press for universal reductions of atmospheric pollution and this is possible, because 98% of the sulphur dioxide from a large plant can be eliminated. The medium sized and small heating plants are the real problems. The Environmental Protection Agency of the United States of

America is to be congratulated on establishing comprehensive standards, making 90% abstraction compulsory; yet these levels of pollution are still too high for the health of monuments, because the effects are cumulative. We still have a long way to go.

Vibration

Vibration is another cause of decay for which no papers have been received. It is difficult to identify the damage caused by vibrations, because except in extreme cases it is identical with the natural ageing process of a building, but again the effects are cumulative. In an intense vibration environment we will probably suddenly be surprised that our historic buildings are falling down earlier than might have been expected. The vibration environment of St. Paul's Cathedral, London, of which I was proud to be the Surveyor to the Fabric before coming to ICCROM, was such that its life would have been halved, however, the City of London diverted heavy traffic away from this national monument so slowing down the rate of decay. Traffic engineers, the police, town planners and those responsible for historic buildings should work together to prevent damage by traffic vibrations, which is proportional to the number of vehicles multiplied by the number of axles and the cube of their axle weight. A heavy lorry can therefore be more than 1000 times more damaging than a private car. Vibration is a local problem except in the case of supersonic aircraft, which, I am thankful to say, are unlikely to be commercially profitable. There is evidence enough to prove that they are damaging to historic buildings; the tower of Fenelon in France collapsed and stones were reported to have been dislodged from St. David's Cathedral in South Wales by the sonic boom.

Vibration investigations are very expensive and take time and sophisticated equipment. In one case vibration could be felt all over a building when a heavy vehicle went over a defective rainwater gulley. The investigation to prove the damage would have cost 30.000 pounds and taken five years, while to repair the gulley and remove the cause of decay would cost one hundredth of this amount. One must keep a sense of proportion and also monitor events by regular inspections.

However, we can only express fears that much more damage is being done to historic buildings than is realized. The phenomenon of heavy is relatively new, so its cumulative effect has not been assessed. ICOMOS should press for much more research in this field, orientated towards the

problems of historic buildings. There are some national standards for immediately recognizable damage in typical modern buildings and levels of particle acceleration have been laid down, but these standards take neither the initially decrepit state of the historic buildings into account nor the effects of cumulative vibration.

Investigation of Causes of Decay

Regular Inspections: within the context of a visual inspection of a building, which should ensure that its conditions is understood as a whole by recording all visible defects, the way a building has been used and abused should be studied and the way it has reacted to both its internal and external environment assessed. A formal report should result from this inspection and this should list actions necessary to preserve the building in four categories.

1) IMMEDIATE: to avoid danger or prevent collapse;
2) URGENT: to stop active decay of materials;
3) NECESSARY: to repair or renew defective parts within a stated time (the bulk of work comes in this category, so it can be carefully planned, in order by trades);
4) DESIRABLE: improvements, alterations, rehabilitation come in this category, which has a lower financial priority.

These regular formal inspections are the basis of a strategy for preventive maintenance of historic buildings with the aim of keeping the nation's heritage of buildings in a wind and watertight condition. In England, under a government measure, medieval churches are inspected at five year intervals and it has been found that the cost of repairs has gone down dramatically, because damage and decay is prevented. Such formal inspections at rather large intervals must be supported by casual inspections by a nominated person to check for damage after storms and for leaks in roofs, and the cleaners of buildings must learn to report any evidence of insect attack or suspicion of fungal attack, as the latter especially can cause major damage to structural and decorative timbers in a short time. The nominated person need not be a professional, but he should have received some instruction and be proud of his building and ensure that the rainwater disposal system is working well at all times, so he must be a local person.

It is curious that a highly organized bureaucracy finds it easier to carry out a major restoration costing millions than to ensure that grass, dead leaves, or the bodies of birds are not blocking the rainwater system, not to say letting trees grow out of the sides of cathedrals and abbeys — but

I have seen such things. My colleague Prof. G. Urbani's paper entitled *From Restoration to Maintenance*, given to Europa Nostra in Brussels last year, marks an important step forward. If one prevents the rainwater system flooding, the wetted timbers will not rot, the roof will not collapse and you have prevented the need for that great work of restoration. In this way the practice of preventive maintenance can be said to be the best form of conservation and to save money.

Further Studies

Visual inspections are also the basis of further studies, that is, investigations in depth into the causes of decay. The amount of time and cost expended must clearly be related to the seriousness of the problem.

These studies are generally related to analysing causes of humidity and decay of materials and also to recording structural movements, which subject is outside the scope of this paper. Guesswork and touch are not sufficient to diagnose the nature of the source of humidity; one must take measurements and find the moisture contours in the area under consideration in order to trace the source if this is not obvious. In addition the internal environment should be recorded for at least a year with a thermohygrograph. The skilled practioner can learn a lot from these readings, provided the calibration of the thermohygrograph has been checked at monthly intervals using an accurate physcrometer.

A word of warning, simple electric moisture meters can be misleading if there are hydroscopic salts in a wall or if condensation is occuring on or below the surface of a material.

As the internal environment varies considerably inside a building, three or four thermohygrographs may be desirable and ideally one should be placed outside to record the microclimate of the building. Most forms of decay of materials are related to water and climate.

We have a good example of an investigation into a wall by John Stewart and Charles Costain and Keith Blades in their *Examination of Salt Related Spalling in the Parliament Building, Ottawa.* Their investigations identify the subfluorescence as an anhydrous sodium sulphate and by taking dry core samples they found the salts located deep in the walls, transported there by rainwater previously contaminated by atmospheric pollution. They recommended repointing the masonry joints and internal dehumidification as the cure. Two points emerge here: first, the effect the internal environment has on the external decay of materials and second, if I may be forgiven for rubbing a point in, the condition of mortar pointing in a highly polluted atmosphere is a vital factor in the plan for preventive maintenance of a masonry building.

The repointing of buildings needs care and understanding. The choice of mortar is a key question. Under pressure of a highly organized industry, which can supply its products anywhere in the world and because industrialized products delivered in bags are automatically believed to be better than traditional materials, we find masons, builders and even architects using Portland Cement wrongly for repointing. This is so disasterous that I have designated Portland Cement as the enemy of historic buildings.

Portland Cement, generally called cement, in its various specifications, is a magnificent material for modern structures which require its strength and quick setting qualities. It can be used in reinforced concrete, with suitable aggregates and iron, to strengthen and consolidate a structure, under professional guidance. It is also frequently misused mixed with sand to form mortar and plaster. But Portland Cement is not designed for use in mortars or plaster on historic structures, which do not require its specific good qualities, but which suffer from its defects and side effects on traditional materials. The following are reasons for NOT using Portland Cement on historic buildings:

1) The use of Portland Cement is not reversible. To remove it damages all historic building materials which also cannot be recycled.

2) Portland Cement is too strong in compression, adhesion and tension, so it is not compatible with the weak materials of historic buildings. It is a paradox that such weak material has the greatest durability.

3) Because of its high strength, it lacks elasticity and plasticity when compared with lime mortar, thus throwing greater mechanical stresses on adjacent material and hastening their decay.

4) It is impermeable and has low porosity, so it traps vapour as well as water and evaporation is prevented. So it is no good for curing damp walls; the reverse is true, for if used it only drives the moisture upwards. If used as mortar its impermeability accelerates frost damage and increases internal condensation.

5) It shrinks on setting, leaving cracks for water to enter and because it is impermeable such water has difficulty in getting out. Therefore, it increases defects caused by moisture.

6) It produces soluble salts on setting which may dissolve and damage porous materials and valuable decorations.

7) It has high thermal conductivity and may create cold bridges when used for injections to consolidate walls.

8) Because of its large thermal movement reinforced concrete is dangerous where thermal conditions are extreme.

9) The colour is " cold " grey and rather dark. The texture is too often smooth and " steely ". These characteristics are generally judged aesthetically incompatible with traditional materials.

For all those reasons Portland Cement should NOT be used for mortars or plasters.

What then could we use in ancient buildings? Simply lime. Up to 1930 all over the world lime was used extensively and the buildings still stand beautifully. The examples of the Pantheon in Rome (built in 27 BC) or the Caracalla Baths (212 AD) are significant, but the traditional methods of burning and slaking lime have been lost in many countries. Traditionally lime mortars in the mix of 1 part lime to 3 parts of coarse sand were used. The sharper and more varied in size of its particles the better the sand. Its colour determines the ultimate colour of the mortar. Its texture can be improved by light spraying to remove " laitence ".

The Internal Environment

The desirability of measuring the internal environment of a building has been mentioned already, but it must be stressed that as a building is a " spatial environmental system " any change will effect the balance of that system.

The most common form of change is the introduction of higher standards of heating; others are air conditioning and humidification or structural alterations. The valuable paper by Kerston Alexanderson, Elmar Brydolf and Ingmar Holmstrom, entitled *Energy Conservation in Churches*, shows how heating by reducing the relative humidity so causing organic materials to shrink and inorganic materials like stone to expand can cause severe strains in the structure. For example, in Meissen Castle in D.D.R., the introduction of heating caused a slender marble column to fracture by increasing the load thereon. We are all familiar with the shrinkage and cracking of wood, but as this paper informs us, the effects of change on materials go much further: painting flakes, internal wall surfaces are blackened, and moisture being evaporated into vapour form will pass through walls and, if cold enough, will condense and may even freeze, causing frost damage; while the rate of salt erosion in plaster and masonry is inevitably increased. In churches polychrome sculpture, painted panels, organs, pulpits and pews are damaged and if artificial humidification is introduced to correct these troubles more

moisture is driven through the walls. In England it has been found that the introduction of heating into historic buildings has caused some traditional materials to fail, especially metal roofs due to the increase of condensation on the underside of the lead or copper sheeting. Also condensation is likely to occur in unheated spaces. Once again, measurement of the internal environment enables one to make correct diagnosis.

Review of Past Methods and Chemicals for Conservation

Often the previous restorer may be designated as the worst enemy of the building. This has happened too often, even in some cases to buildings of international importance. The failures are caused generally by lack of understanding of the nature of materials and long term effect of climate and environmental stress. Ms. Collette di Matteo has reviewed the use of *Silicate and Fluosilicate Stone Preservatives* in France in the 19th Century. Such reviews are healthy and salutary and depend upon accurate documentation of the chemicals and processes used, and show how effective they have been in the long term.

It would be very useful if ICOMOS, through its National Committees, could review the value of past practices. If they have delayed decay they have been useful, but because they are considered old-fashion they tend to be ignored, but it must be said that an old-fashioned preservation receipe in the hands of a man who knows how to apply it, is much better than a scientifically superior receipe, if the person applying it does not do so exactly right.

One problem the architectural conservator has is the continuing availability of dependable chemicals. Sometimes he is forced to use a chemical designated only by its trade name and the manufacturer, fearing commercial competition, refuses to give its analysis. One way out of this impasse is for the manufacturer to deposit a sample of the chemical in a safe place (like a bank) together with its analysis. Then if necessary the sample can be retrieved at a later date. Another aspect of trade names is that the manufacturer can alter the formulations without notice, but with disasterous results for the conservator. A " white list " of known chemicals which manufacturers agree not to alter would be of immense benefit to conservators.

Field tests of materials are highly desirable, but care must be taken in publishing the results as commercial interests are liable to take legal action against persons making comments unfavourable to them. This is why so many reports seem rather inconclusive.

One test of twelve stone preservatives marketed commercially, showed that two hastened decay, two changed the colour of the stone and eight had no effect. The preservatives continued in use because few people read the report.

New Materials and Safety Hazards

Manufacturers should indicate clearly all the conditions under which chemicals can be used. No one should be ashamed of wearing helmets, steel-soled boots, goggles, masks, respirators or protective clothing if the manufacturer recommends these precautions.

Research: Stone and Mortars

The paper on the façade restoration of the Renwick Gallery of Art, *Materials Investigation and Architectural Analysis* by Holles J. Stevens, S. Z. Lewin and A. E. Charola is interesting, being based on the scientific analysis of the physical properties of the stone from which the Renwick Gallery is built. The mismatch between the thermal properties of the stone and resinous additions is a warning to us all and we must remember that stone and brick masonry expand and contract with changes in their humidity.

Often, if there is a mismatch between materials, it is the mortar joint that acts as a cushion, so the elastic and plastic qualities of mortar and the width of the mortar joint are questions worthy of study. There is a small research team under G. Torraca which is investigating these questions at ICCROM. Various mixes of lime mortar are being tested to find out their properties. Pure lime mortars are rather slow to set and this objection has been raised in some cases. The addition of pozzualanic material however alters their characteristics radically.

The Romans discovered that the addition of a natural pozzualanic earth of volcanic origin, found originally at Pozzuoli, greatly increased the strength of their lime concrete and mortar mixes and on testing this has been discovered to be very flexible. This may be the secret of the durability of Roman ruins, enabling them to resist centuries of environmental stress. If natural pozzualana is not available, it is possible to use crushed bricks or titles as an artificial pozzualanic material and other additives such as wood ash and the juice of trees, as well as ox blood, have been used to improve lime mortars. Ancient technology is full of seemingly bizarre receipts. Modern

additives with a pozzualanic effect are pulverised fly ash, a by-product of coal burning power stations and fluid coke, a by-product of the oil refining process available in the U.S.A. [1] There may be many uses for fluid coke when gap filling characteristics are required, as it releases gases on setting and causes the mortar to expand. At ICCROM we are hoping to test all these alternatives, but this takes time. A seminar on the subject of mortars and grouts is proposed this autumn.

Ms. Simonetta Peroni's paper on the analysis of mortars in the small early Christian church of San Benedetto, Rome, is significant because this analysis helps diagnose the phases of the construction in combination with historical and documentary studies.

The contributions of the ICOMOS/RILEM Committee on Stone are most important and for those specially interested I would refer you to the pre-prints of the RILEM/UNESCO Conference of Paris, 1978, when many valuable papers were given. The ICOMOS/RILEM Committee, a multi-disciplinary group, under the Chairman M. Mamillan, has issued a valuable schedule of thirty-five tests for stone and does valuable work in co-ordinating research. The results of ongoing research are transmitted by experts at the UNESCO/ICCROM courses held in Venice.

Research: Architecture of Earth Materials

Increasing awareness of the past, present and *continuous* use of earth as a building material draws our attention towards the main efforts concerning the conservation of the architectural heritage built of earth.

The ICOMOS meetings at Yazd, Santa Fe and Ankara, are probably the activities that best represent this increasing concern to identify and categorize national and international developments in the conservation of earthen architecture and structures.

Let me briefly refer to the recommendations of the latest of these international workshops (Ankara, 1980). Through this meeting, the following important considerations were laid down:

— An initial identification and assignment of significance to the expression " earthen architecture " contrasting the limits of the terms " adobe ", " mud-brik ", " pise ", etc.;

— The distinguishing characteristics of natural deterioration processes and that of those introduced by man in the deterioration of earthen architecture were emphasized;

— The representative cultural character of vernacular architecture and the need to implement policies to consider its preservation were stressed;

— The use of traditional methods and materials for the preservation of earthen architecture was encouraged, since these are often highly compatible with the characteristics of earthen building materials; and, especially, because of the important contribution that these methods and materials make to the organic quality of architecture of earth, particularly as it relates to its inhabitants.

Various categories for the appropriate preservation of earthen archaeological resources were also considered in order to:

— Give immediate temporary protection to newly excavated mud-brick material, until a definite conservation plan is established for these structures;

— Provide adequate protection against direct erosion by rain or melting snow, and sufficient thermal insulation to avoid condensation or the " greenhouse effect ";

— Include provisions to drain rainwater and avoid erosion at the base of the walls; and

— Consider

a) immediate backfill, periodic maintenance,

b) emergency consolidation and backfill,

c) emergency consolidation and temporary protection, or

d) complete conservation of sites which have been left exposed to the environment, as options available for their preservation.

Research needs were identified on lines of:

— Appropriate preservation techniques with emphasis on traditional methods and materials;

— Design of modular systems for the construction of low-cost protective shelters for earthen structures;

— Standardization of test methods; and

— Multidisciplinary pilot field projects.

These are only a few of the many considerations laid down in the latest international meeting. However, they give us an overview of the specific needs we have to meet *now* in the preservation of earthen architecture.

Research: Wood

To date most of the research work on conservation of wood has been done in Japan and the papers of the International Symposium on the Conservation of Cultural Property 1978, *Conservation of Wood* published by

the Tokyo National Research Institute of Cultural Properties under our Chairman, the Director General, Dr. Nobuo Ito, make a most valuable contribution.

We are most grateful for his paper entitled *Wood-as a Material for Japanese Buildings*, which gives a most interesting picture of the different woods used and the history of Japanese wood technology which provides the world with both the oldest wood building, a pagoda from AD 670, and the largest wood building, from the 13 th Century. The greatest danger to these precious buildings is fire, followed by termites and fungus. Only constant vigilance can preserve them. Vitruvius, writing in 31 BC, bewailed the fire risk from wattle and daub partitions — the risk is still with us.

A further conference is planned for 1982 and will be sponsored by UNESCO, who also are considering initiating short courses on the same lines as the Venice courses in stone. This will encourage research and documentation of information in this large field.

Conclusion

We face a vast task in considering the conservation of materials and materials for conservation. Field workers, like architects, engineers and planners, have to learn how to communicate with scientists and scientists have to be persuaded to leave their laboratories and to learn how to look at buildings. By analysing visual evidence with an understanding eye they will be able to eliminate some of the bewildering variable factors and apply their powers of research to the vital questions, but it is impossible to pose these questions without understanding the internal and external environment of a building, assessing the environmental stress to which it is subject.

May I suggest that the conference discuss the papers and consider whether any resolutions are necessary. The suggestions I have made in this paper are summarized as follows:

1) Every country should record its traditional crafts and take steps to maintain living knowledge of ancient skills and technology.

2) Histories of the technology of the Pre-Colombian Americas and of East Asian countries are requested from UNESCO to assist conservation studies in these regions.

3) ICOMOS National Committees to be asked to provide more information on the typical causes of decay of buildings in their countries, with particular reference, e.g. entomological causes, atmospheric pollution and acidity of rain.

4) Research into reduction of atmospheric pollution from small and medium sized heating plants should be initiated in a UNESCO programme.

5) Research into the problems of historic buildings and cumulative damage from traffic vibration to establish suitable standards is requested from governments under co-ordination by UNESCO.

6) Investigations into the effectiveness of earlier techniques of stone and wood preservation should be carried out by National Committees of ICOMOS.

CAUSES OF DECAY AND DAMAGE TO CULTURAL PROPERTY

EXTERNAL CAUSES OF DECAY: The SUN produce LIGHT with ULTRA VIOLET INFRARED (HEAT) RADIATION

Climatic Causes

- seasonal temperature changes
- daily temperature changes
- precipitation of rain and snow
- ice and frost
- ground water and earth moisture dust

Biological and Botanical Causes

- animals
- birds
- insects
- trees and plants
- fungi, moulds, lichens

Natural Disasters

- tectonics
- earthquakes
- tidal waves
- floods
- avalanches or landslides
- volcanica eruptions
- exceptional winds
- fire

INTERNAL CAUSES OF DECAY, (Note: the building modifies and protects)

Humidity
- Excessive dryness
  - Embrittlement by desiccation
  - Damage to marquetry
  - Slackening of canvas
- Rapid changes
  - Movement of hygroscopic materials
  - Warping of wood
  - Flaking of paint
  - Activation of soluble salts
- Excessive wetness
  - Damp Heat — Fungi Bacteria
  - Weakening of adhesives
  - Rotting of size
  - Staining of paper, vellum etc.
  - Blurrings of inks
  - Mildewing of leather
  - Metallic corrosion encouraged
  - Loss of adhesion of illuminations
  - Adhesion of loaded papers
  - Tightening of canvas

Contaminated Air
- Sulphur dioxide
  - Bleaching Tendering
- Hydrogen sulphide
  - Blackening of lead pigments Tarnishing of metals
- Soot, Dust
  - Staining

Neglect
- Accident
- Fire
- Exposure to excessive light, heat and humidity
- Careless handling and packing
- Inadequate storage
- Pests
  - Moth
  - Wood Beatles and Silverfish
  - Termites etc.
  - Rats and Mice

MAN-MADE CAUSES OF DECAY:

- neglect of preventive conservation
- wars
- purposeful alteration
- environmental pollution
- water abstraction
- excessive heating
- vandalism and arson
- theft

* Grateful acknowledgement to H. J. Plenderleith and A. E. Werner. *The Conservation of Antiquities and Works of Art*