'Appropriate technologies' in the conservation of cultural property

Protection of the cultural heritage

Technical handbooks for museums and monuments 7

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Unesco: *Appropriate technologies in the conservation of cultural property*

Preface

It has been increasingly felt among conservation specialists in recent years that the search for 'appropriate' or 'intermediate' technology is as relevant to the conservation of cultural property as to economic development, where the concept first developed. In rural development and small-scale industry in particular the importation of sophisticated capital-intensive technology has not only been an extremely heavy financial burden on developing countries but has often generated conflicts and imbalances as well. Hence the search for techniques that might mobilize local capacities, especially human resources, in the most effective ways possible, and encourage people to invent the methods and processes best suited to further their own productive potential.

Borrowing the most advanced conservation technology from industrially developed countries is not always necessary or desirable. It can even be self-defeating, especially when — as is often the case — the energy and hardware required are too expensive to obtain and maintain.

Advanced technology may also be geared to modes of work organization and to work relationships that jar with the traditional (but changing) societies to which it is transferred. Not that modern technology is to be systematically shunned, for this would run counter to the common sense of all conservation work. But the hankering after the most up-to-date equipment and materials reduces people's awareness of the possibility of exploiting older, traditional technologies in a creative way. There is always an ideal 'mix' to be discovered, the right balance between old and new.

Unesco's Approved Programme and Budget for 1979–80 (20C/5) provided for the study of 'the use of traditional techniques and materials as well as local manpower and resources adapted to socio-economic realities and modern requirements' in relation to the conservation of cultural property. Requests for information and contribution on the subject have been addressed mainly to specialists active in Unesco cultural-safeguard projects, but also to other conservation experts, whose work has been brought to our attention. The results of this data search have not proved overly abundant. This is no doubt partly due to the fact that, while many specialists in the field in developing countries have long practised one form or another of 'appropriate technology', this has been done under such specific conditions that it has not occurred to them that the process could be of wide general interest.

The present volume brings together five contributions, each of which approaches 'appropriate technology' in an original and constructive way, reflecting the many directions theory and practice on the subject do in fact take.

The first chapter describes the revival of some of the rich craft traditions in Nepal, which were subsequently employed on a wide range of buildings in the Kathmandu Valley in dire need of restoration. The second chapter reports on a series of ingenious engineering solutions devised by a young architect in Tunisia for the reconstruction of ancient Roman monuments. The same author also discusses earlier work done on the Karnak temples in Egypt, which made optimal use of sheer inventiveness and a large labour force in order to move extremely heavy ancient structures. The third chapter discusses some of the ancient methods used in India for the conservation of materials, and mentions the need for scientific research to determine why these traditional solutions have proved effective. In the fourth contribution, special techniques for the restoration of mud-brick structures are described, after the methods of construction of these buildings have themselves been explained. In the final chapter, the very notion of the 'appropriateness' of a technology, in the sense of one that least disrupts a traditional cultural harmony, is seriously questioned on a theoretical level. The argument is illustrated with concrete examples drawn from the authors' own practice. While the conception criticized by the authors is not precisely that of the revival and creative re-use of the traditional skills, which seems to be the concern of the majority of writers on the subject, this concluding series of reflections pin-points the very close 'bond' that must exist between a user and whatever technology he chooses, if the latter is to be truly successful.

The sheer variety of these points of view reflect the range of situations involved in the search for 'appropriate technology' in the conservation of cultural property. In bringing them together in this volume it is our hope to show what can be achieved with existing, if dormant, resources and to stimulate further reflection on the subject.

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Traditional crafts and modern conservation methods in Nepal

John Sanday

INTRODUCTION

The importance of Nepal's vast heritage — its magnificent landscapes, its historic buildings, its works of art — are renowned throughout the world, the more so now because of the ever-increasing number of tourists who come seeking the rich culture that still thrives in this unique country. Nepal's proximity to India and Tibet also combine to make it a country of great cultural wealth, indeed a living museum. As Nepal was closed to the outside world until 1951, it was able to preserve its traditions and keep them alive; but today the ever-increasing influence of the modern world and the impact of tourism are disrupting this culture. The future plight of the historic buildings and landscapes of Nepal has not received wide publicity. The fact that the structures are crumbling under the onslaught of each monsoon, and the fact that landscapes are being stripped of their trees and slowly washed away are scarcely apparent to the untrained eye. Unless their predicament is realized and some positive action taken, the unique Nepalese culture that has hitherto successfully withstood the ravages of time will disappear quietly.

Nepal is classed as one of the twenty-five least-developed countries and understandably the pressures on both the government's budget and that of bilateral and multilateral funds is considerable. Nevertheless, the Nepalese Government have been fully aware of the problems facing their country's culture, and in 1956 the Ancient Monuments Preservation Act was introduced in an attempt to provide a nominal safeguard for monuments and to stem the illicit traffic in antiquities.

As early as 1963, consultants from Unesco were sent to investigate the preservation of historic monuments and archaeological sites. This mission was later followed by several investigations by Unesco consultants into the development of cultural tourism, and these eventually led to the establishment of the conservation programme at the Hanuman Dhoka Royal Palace in the Kathmandu Durbar Square, and the proposal for a fully integrated report, 'The Master Plan for the Conservation of the Cultural Heritage in the Kathmandu Valley'.

The first demonstration in the field of building restoration was undertaken as a gift from the Federal Republic of Germany on the occasion of the wedding of His Majesty King Birendra to Queen Aishwarya. A group of architects from

Darmstadt University carried out, at the invitation of the Government of the Federal Republic of Germany and the Nepalese Government, between September 1971 and May 1972, the comprehensive restoration of the Pujarimath, one of the finest buildings of the former Malla Kingdom of Bhaktapur. Its impact on conservation activities in Nepal was extensive, as it set an example of what could be done to a building that was doomed.

The Unesco/UNDP contribution began at about the same time as the Pujarimath project, first with their assistance in the preparation of a detailed inventory of the monuments and sites in the Kathmandu Valley and later in the repair and conservation of part of the Hanuman Dhoka royal palace.

The 'Inventory of Monuments in the Kathmandu Valley', prepared in collaboration with the Nepalese Government and with the assistance of a United Nations expert, calculates that 80 per cent of all historical buildings in Nepal are to be found in the valley. The inventory has selected and identified 888 monuments and has proposed thirty-four monument zones (small groups of religious buildings) and thirty-two preservation districts (small villages or town cores), as well as twenty-four natural preservation districts (constituting park sites, forests and recreation areas). Being a selective list, it has not attempted to cover the lesser shrines of minor historic importance, which in themselves number many thousands.

The Hanuman Dhoka conservation project was mainly intended to establish a training programme for both administrative staff and building craftsmen. It is hoped it will ultimately become a specialist division for the conservation of both monuments and sites — a conservation project office — and act as a co-ordinator between the various government departments concerned with conservation. It is hoped that it will also be responsible ultimately for executing all such works proposed in the Master Plan Programme for the Conservation of the Cultural Heritage in the Kathmandu Valley.

The conservation programme in the Hanuman Dhoka has acted as a testing ground for many techniques in repair and conservation. The beautiful carvings on the Basantapur Tower, cleaned of their original coatings of paint, bear testimony to weeks of experimentation and exacting work by the special cleaning section set up in collaboration with the central conservation laboratory. The reconstruction of the special brick with the co-operation of a traditional brickyard represents a major step in the salvaging of a former craft on the point of extinction. The adaptation of modern techniques for the consolidation of crumbling structures, and the introduction of special insecticides, herbicides and waterproofing agents to protect and prolong the life of the fabric of this priceless building, are but a few of the successful achievements of this project. No doubt the ultimate glory for the Hanuman Dhoka conservation project was its prominence as the backdrop for His Majesty King Birendra Bir Bikram Shah Dev's coronation in 1976.

One of the more noteworthy features of building in Nepal is that the traditional crafts are still very much in evidence. In the paragraphs below dealing with craftsmen and their crafts, a record of the basic crafts incorporated in traditional building is listed and the traditional techniques explained. Where a traditional craft has been expanded to incorporate a modern conservation technique, this will be separately explained.

Several techniques for building conservation have been derived from the four years of experience gained in the Hanuman Dhoka conservation project. It has been interesting to see how experiments and innovations studied and tested in the first stage of this project have become standard practice in the field of building repair over recent years. In the latter years of the Hanuman Dhoka project, the procedures have even become routine amongst the more experienced craftsmen. One of the more important factors in the policy adopted, has been that only locally available materials and skills have been used. All the information on the new techniques, with the exception of the chemicals for timber treatment, have been made of practical value to the local Nepalese administrators and craftsmen. One of the most important factors is maintenance. If a proper maintenance programme is followed, especially on those buildings that have already undergone renovation, valuable funds can be saved for the more urgent cases.

A selection of case-studies follows, giving illustrated examples of repair and conservation, with particular reference to the Hanuman Dhoka, but also including relevant information on other building types. This study ends with a discussion of a particular conservation problem concerning a group of buildings that were unstable. The original proposal was to demolish the buildings and to rebuild them. A true example of conservation resulted, in that the buildings were finally consolidated in their unstable position with the use of reinforced concrete.

THE TRADITIONAL BUILDING CRAFTS AND CRAFTSMEN OF NEPAL

In the history of Nepalese architecture there has been no extensive record in the form of drawings, written accounts or photographs. Nor has there been an attempt to make an academic inventory of the buildings of the Kathmandu Valley or of the architecture of the other regions of Nepal. The traditional building crafts in the Kathmandu Valley, more especially, have survived over many centuries down to the present day as a fine record in themselves of the art and architecture of Nepalese culture.

The craftsmen belong almost exclusively to specific castes, very similar to the guilds in Europe; they mostly carry out the particular craft associated with their caste, the skills of which are handed down from father to son. These skills, despite the fairly drastic events in the history and development of this unique country, have managed to survive.

Comparatively speaking, the quality of work executed by these craftsmen nowadays shows very little 'artistic' flair, because they follow tradition. Throughout the development of the traditional architectural style in the Kathmandu Valley, it is true to say that there has been very little innovation in the true sense of the word; it is therefore more correct to define the art and architecture of the valley and possibly of all Nepal as folk art, a craft handed from one generation to another with almost no change and, probably more important, with no academic or aesthetic criticism levelled at the artistry produced.

These statements are not intended to diminish in any way the intensity of the work produced by the craftsmen; it is highly expressive of Nepal's culture and is the result of the strong religious motivation and dedication of its creators. The craftsmen described in this section are mostly from the Kathmandu Valley, but references will be made to some of the specific craftsmen from the hills and the Terai.

The craftsmen of the Kathmandu Valley

The craftsmen of the Kathmandu Valley are predominantly Newars. The Newars can best be described as a society with a cultural identity, as they are not classified as an ethnic group. At one time, before the conquest of the Kathmandu Valley, they were a nation apart; today they are fully integrated into the social structure of the valley but still maintain their individual identity.

The Uray caste, consisting of craftsmen and merchants, as well as the Jaypu or farming caste, provides most of the building craftsmen. These are subdivided into family groups, such as the carvers (*silapakar*), the metal-workers (*tamrakar*), the roofers (*awa*) and the stone-masons (*lohakami*), to name but a few. The Jaypu caste provides the bricklayers and many of the semi-skilled labourers.

There now follows a brief description of each of the salient crafts, with information on the type of work that can be expected of each group.

Carvers–silapakar

Originally, the work of the woodcarver was very specialized because it required extensive knowledge concerning iconography and the religious significance of decoration. The complexity of an ornately carved deity, multi-handed and holding symbols all of religious significance, requires not only great knowledge of the religious texts but also the skills of a craftsman competent to execute the work. For this reason, family groups are usually formed with the head of the family acting as the teacher to the younger generations, handing down both his religious knowledge and the skills of his craft to his sons, nephews and grandsons. Only when his eyesight fades does he hand over the leadership of the group to his next of kin.

Today, however, it is quite usual to find other family groups, for instance the goldsmiths (sakyes), who for various reasons may have had to change their trade, but lack the specific knowledge and tradition of the true carver, taking on the work of woodcarving and producing some very fine and delicate work as a result of their earlier skills. A once greatly protected craft is now open to the challenge of other artisans.

It is not possible to describe the intricacy or the beauty of the craft in a few lines. Its scope is immense. The elements, such as doors or windows, are broken down into several individual pieces, according to the size available and the characteristics of the local timber. As the timber is usually carved in a 'green' state, allowance has to be made for considerable movement and shrinkage. Therefore, all the joints are of an interlocking nature and formed in such a way that neither metal fixings nor gluing are necessary. The infill grilles of the windows are formed from two interlocking carved battens that are locked in place by a third plain batten slotted in behind as the key. The frames and lintels of the doors and windows are made of several clusters of pillars or cross members, all set into a common base and head dovetailed into the main supporting lintel or cill. The actual carved motifs and decoration on the doors and windows have not yet been closely studied to ascertain whether any specific pattern is followed, but the orientation of these elements is often depicted by specific lesser deities or mythological beasts, which again add to the complexity of the traditional knowledge of the craftsmen.

The tools used by these craftsmen consist of the standard carpentry tools, albeit of better quality than those used by the carpenters. The hand adze, especially those of the older craftsmen, has a curved handle, often made of horn, and a straight blade that is kept razor sharp: the opposite to the utilitarian model used by the carpenters, which has a straight handle and an angled blade. The head of this type of adze is weighted and serves as a heavy hammer or mallet. The carver has a great quantity of chisels, about twenty-two in all, ranging from broad gouges down to small headed chisels formed from bicycle spokes. Nearly all the carving chisels are made by the local blacksmith under the guidance of the craftsmen, and the best steels are acquired for manufacture of such tools, as for example unwanted car springs.

The timbers commonly used by the carvers are sal (*Shorea robusta*), chaap (*Michelia champacca*), haldup and sisau. The first mentioned is the most commonly used in buildings, and is extremely resilient. It is generally carved in a green state as previously mentioned, since when seasoned it tends to be very brittle along any sharp edges, whereas when the sap is still in the timber it cuts more easily. Unlike most of the other timbers, sal is very resistant to all types of fungus and wood-boring insects, and only in extreme cases is it liable to be attacked.

The scope for training woodcarvers is at present almost non-existent. Recently, an organization known as Sajha, which is affiliated to the Government of Nepal, has given its support to the proposal for training craftsmen attached to the Nepal/Federal Republic of Germany urban development programme in Bhaktapur. Otherwise, the only possibility for training lies within the family groups, where the younger generation is apprenticed to the group. During the recent Hanuman Dhoka Conservation Project, young carvers were encouraged to train, and proposals were even put to the Ford Foundation of the United States of America to provide funds for the setting up of a specific woodcarving studio for the purpose of encouraging training amongst the craftsmen, with the most experienced member of each family group acting as the tutor to a collection of younger apprentices. It was also planned to set up a research section within the studio which would study the traditions, the decorations but above all the iconography. A photographic library was also proposed, to record all the different types of windows, doors and roof-struts as well as the motifs and decorations used to adorn the temples, palaces and traditional dwellings.

Stone-masons—lohakami

In the valley, both masons and stonecarvers are sparsely represented. In and around the Kathmandu Valley there is a limited supply of decent building stone. In the past most of the 'prestige' stone buildings were built from a stone that had been transported a considerable distance. It also appears that the stonecarvers do not have the same affinity with their material as do the woodcarvers. On a smaller scale, however, most small Newari Buddhist shrines, individual deities and elements of decoration such as butterlamps, pillars, and wall bands incorporated into the temples and palaces are often of stone. Today, the woodcarver will often double as a stonecarver, and many of the woodcarving families are descended from a stonecarving family. Most of the stonework carried out today consists of paving for roads and block cutting for kerbs around temple platforms.

The stonecarvers use a fairly extensive range of bolster-type chisels whereas the stone-dressers or masons may use as few as three or four chisels and a heavy club hammer.

The available stone comes mostly from the rim of the valley, and recently a good supply of marble was uncovered on the southern edge. Otherwise, the stone used is a hard, greyish limestone that is by no means ideal for carving or shaping. There were said to be some old quarries on the other side of Kirtipur which supplied the stone for many of the stone temples built before the arrival of the Shah dynasty. Some of the stone used for carving the more important deities was probably brought up from India.

The carpenters—sikami

Many of the apprentices to the carvers start off as carpenters, but it is again more usual for families to set up their own groups. The traditions of the carpenter are not as strong as those of the woodcarver and, as a result, it is often the case that individual carpenters will be accepted into a group even though they may not come from the same village. Today in Kathmandu, there are opportunities for training in carpentry at the Engineering Institute where the theory of woodworking is taught, and apprentices are trained to use power-driven machines. Unfortunately, at present there is no training in the use of traditional tools, and the courses are in no way related to domestic or village requirements. However, under any renovation programmes carpenters who have taken the training will soon learn traditional carpentry techniques and be able to add this to the useful knowledge they have already gained in their courses.

The knowledge and skills of the traditional carpenter often make him the most important man on the building site. All seem to possess a good general knowledge of building; theirs is by far the most important and essential trade on the site of a conservation and repair project. Not only do they carry out all the major structural work, e.g. the framing for the walls, the floor structure and the roof structure, they also prepare the shuttering for concrete and construct any of the necessary shoring and temporary supports to the building under repair.

The timber most commonly used in the Kathmandu Valley and in the lowlands of Nepal for building work is the salwood tree, which is a relatively expensive timber. For domestic buildings, therefore, a softwood such as pine (sala) is normally used. Other timbers, already mentioned under the carving section, are also used, but for more specialized work such as furniture-making or decorative floors.

Sawyers, who are responsible for cutting timbers to the correct section, can also be included under this heading. These men are often carpenters who have paired up with a relative or friend, have bought a pit saw and are prepared for the arduous task of planking and cutting large baulks of timber to the required sizes.

The tools used by the carpenters are all standard tools, but perhaps the most useful is the hand adze which is used for roughing out the shapes of timbers and trimming them to a square section. Sal timber is liable to spring when it is slab sawn and therefore has to be squared up before it can be incorporated in a building. Jack planes, set-squares and mallets are usually made up on site, and only the metal parts are bought from the market, as are the standard chisels.

As already mentioned, training is

available at the Engineering Institute; however this is at present limited to machinery handling. Carpenters who are interested in working on traditional buildings would benefit from a short orientation course on a conservation and repair site under a specially trained and competent craftsman, who has had extensive experience in such work. A course of this nature could easily be worked into one of the proposed conservation programmes outlined in the Master Plan.

Roof tilers–awa

On the roofs of the traditional buildings of the Kathmandu Valley is laid a very particular type of tile — *djigati.* This is a small clay tile measuring 20 × 10 cm, which is specially shaped to overlap, and bedded directly onto a clay base. Considerable skill is required for the laying of a large roof, and this work is undertaken by a particular family known as Awa. These craftsmen, when not working on roofs, work in the brick fields making the tiles that they use. However, as this type of tile has now been broadly superseded by a larger interlocking tile and the advent of sheeting materials and the flat roof, the Awa are usually involved in the making of bricks.

The craft of laying these roofs is threatened, since only repairwork is called for and, as a result, the need for apprentices is almost non-existent. As explained in the section on conservation techniques, a method has been evolved and proved to make this type of roof-covering a viable proposition. The few remaining working family groups should therefore be encouraged to take on more trainees to continue the important work of replacing the roofs of historic buildings, as well as that of their maintenance and repair.

Bricklayers—dakami

There does not appear to be a specific caste or group for the bricklayers as such. Most of these craftsmen come from the Jaypu caste, and only work as bricklayers when the seasonal agricultural work is complete. The family names of these men are Dongol and Maharajan. They are closely associated with the brick-kilns and the families that run them. (See *Brickmakers* below.)

The tools used by the bricklayer consist of an all-purpose tool, a combination of a trowel and a cutting hammer, used for shaping the brick, cutting a simple moulding, or preparing the mortar bed for the bricks and pointing up the joints. The tool is shaped like a chopper with a turned-up pointed end, the point being used for the decorative cutting. Other tools used are the plumb bob and a water level consisting of a long length of transparent polythene piping filled with water.

The work carried out by the bricklayers ranges from very simple brickwork laid in a mud mortar to the more sophisticated work of laying the special wedge-shaped brick — *telia int* — that was a common but highly attractive walling used in the Malla period. This type of brickwork demands considerable care and accuracy, as the brickwork relies for its effect upon the very tight joints achieved between the bricks. It also requires a considerable knowledge of traditional building methods and close liaison with the carpenters.

The training available to bricklayers is again limited to that offered by the Engineering Institute's trade courses. Unfortunately, there is little reference in such courses to traditional brickwork. Bricklaying or masonry is a trade in need of encouragement and it is suggested that a simple training course should be incorporated in any of the proposed conservation and repair programmes.

Bricklayers can also be made responsible for the structural concrete work that is essential in most repair work. This work, which is often highly skilled, is closely associated with the repair of brickwork and can usefully be included in such training programmes.

Brickmakers—appu

Today, brickmaking throughout Nepal has become a highly commercial undertaking. Brickmakers have adopted the rotational-kiln method of firing the bricks, an innovation from Europe via India. As a result, vast quantities of bricks, most of them of rather poor quality, are now being made in the Kathmandu Valley. A number of these kilns are worked by family groups, following the traditional skills and making the original Malla style of brick and tile which were commonly used on all buildings throughout the valley in the sixteenth and seventeenth centuries. This particular technique has survived solely thanks to the demand for these bricks in the Hanuman Dhoka conservation programme. (See *Brick and tile making* below.)

Although considerable research has already gone into the method of manufacture of the traditional clay products, the results do not yet match up to the original models and it would therefore be of value to this growing industry if further studies and research could be carried out in this field.

Metal-workers—tamrakar

The metal-workers are only indirectly associated with building work, in that they are responsible for most of the ornamentation. It is, however, a thriving traditional craft, which has survived more thanks to the requirements of tourism than to local demand. As a result, there are several family groups in Patan in strong competition with one another, who are willing to prepare and make anything in metal. The cost of such work is relatively high, as it appears that these particular craftsmen are among the few groups who realize their potential value to the community.

Decorative work such as the casting of bells, or *repoussé* work to adorn door surrounds, are skills that will continue to thrive; but one of the crafts directly related to building that is no longer practised to any great extent is that of laying sheet metal roofs. Copper or brass roofs are a common sight on many of the more important temples. These roof coverings are not used nowadays mainly because of the great expense of importing the material.

It was necessary to lay a very complicated roof on the dome-shaped Kirtipur Tower during the Hanuman Dhoka conservation project. For this it was necessary to train the members of one of the metal-working groups in the modern techniques of laying a copper-sheet roof. It was, perhaps, the most complicated roof that they had ever been confronted with, but the work was achieved with great skill and success. As long as sound technical knowledge and guidance are available these men can achieve almost anything that is possible in metal-work.

Blacksmiths—nakami

These people come from the Kau caste and, like the Tamrakar family, are a fairly close-knit group. Their work is basic forge work, ranging from the making of agricultural tools to the execution of skilled lathe work. Some of the wealthier families have imported metal-working machinery from India and have set up very good workshops capable of carrying out most metal-work required in construction and repair work, i.e. the making of steel shoes, brackets, braces and various special metal fixings.

As conservation and repair work is specialized and there is a considerable amount of metal-work involved, it has been suggested that it would be economical to set up a special unit within a repair and conservation unit.

Semi-skilled labour for cleaning woodcarvings, etc.

This was a newly formed group, comprised mostly of females, trained in the conservation laboratory to clean and remove paint from the carved timber elements on a building. (See *Woodcarvings and their cleaning and consolidation* below.) Young Jaypu girls were chosen because they were hard-working, careful and not afraid to climb on the scaffolding. They would also carry out any other light labour when called upon.

The labour force

The male labour force can be made up of the male members of the Jyapu caste; however, their work is seasonal as their main responsibility is to their land. They cannot, therefore, be relied upon as a constant labour force. It is more usual to use a labour force made up of members of various hill tribes that come into the valley to earn money and who have been given leave of absence by their families. These people are generally Tamangs, who are strong, hard-working and loyal. They find lodgings in the towns and are willing to work from dawn to dusk. When information is received that work is available, it is usual for these Tamangs to form themselves into large groups made up of many different members from one village; each group is the responsibility of a selected leader, who also ensures that the full complement of his labour force is maintained.

Plasterers

Plaster and stucco work is most common in the lowlands of Nepal, where an Indian tradition has been followed. In the Kathmandu Valley, only the palaces built under the direction of the Rana families are plastered internally, and with stucco work externally. Their inspiration was derived from the neoclassical buildings of Europe, and it is often said that much of the finer work was done by craftsmen specially brought from Italy. Craftsmen of such calibre are no longer to be found in the valley; however, down in the Terai (where this type of work, although not so ornate, is commonplace) it is still possible to find craftsmen in plasterwork.

The craftsmen of the Terai still appear to be masters of such trades as brickwork, tiling, plastering and concreting; some of the older artisans still practise the traditional methods for preparing their plaster.

If programmes for the conservation and repair of these stucco buildings are foreseen, it is important that these craftsmen be given encouragement to maintain their traditions. For this reason, it is recommended that a stucco building of importance be chosen for inclusion in the long-term conservation programme, if only as a training ground for these craftsmen.

Mural painters of the Northern Regions

It is difficult to classify these artists solely as building craftsmen, as part of their religious duty is to paint religious scenes on the walls of temples, monasteries and chapels in private dwellings as well as on canvas scrolls (*thankas*) for religious use amongst the Buddhist community. These artists are specially trained, engaged by communities, and paid for the execution of their work. Many of them are monks or belong to a religious community.

These artists are mentioned under this heading because their tradition is slowly dying out in the Northern Regions, and it is important that efforts be made to help promote this important art form. It is almost impossible to define clearly where religion ends and the work of saving a cultural heritage begins; however, in regard to the repainting of religious scenes, it has been observed that many important historical murals have been overpainted with more modern subject-matter, thus spoiling an important part of Nepal's cultural heritage.

It is here that education and guidance can help mural artists, and to this end it is suggested that one of the older established monastic communities should be sponsored to promote their training.

There are, of course, many other crafts and craftsmen to be found in Nepal, and even some who are involved in traditional building work. This list is not intended to be exhaustive and its purpose is to establish the need for encouraging and training craftsmen in the traditional crafts that are an integral part of Nepal's cultural heritage. It will also help, and possibly encourage, those people who have recently become involved in traditional building, in their task of finding and training craftsmen. It should not be forgotten that without its craftsmen, Nepal would find it impossible to maintain its cultural heritage.

TRADITIONAL CRAFT SKILLS REVIVED IN A MODERN SETTING

During the four years of the Hanuman Dhoka conservation project, one of its most rewarding aspects was the extent of results achieved by relying almost entirely on local resources and materials. It was necessary to simplify and to adapt modern conservation methods to local materials and techniques, particularly in respect to structural consolidation and repair work. Various castes have been employed in different processes: the Kau or Newari blacksmiths have been responsible for much of the metalwork, and the wind bells have been made in a number of different households in Patan, especially by the Newari Tammo caste. Copper roofing to be used in the Kirtipur Tower is to be replaced by craftsmen from the Tamrakar caste.

Brick and tile making

The rediscovery of the method of making the original *telia* brick used in the Malla building era was a considerable achievement. The *telia* or oiled brick is no longer used in Nepalese architecture and its technique was completely forgotten.

In the Hanuman Dhoka conservation project it was necessary to replace many of the defective bricks with sound ones. The practice previously had been to use salvaged bricks, but this is not a satisfactory method, since there is a growing demand for bricks as more and more historic buildings are being dismantled and rebuilt. The importance of rediscovering the technique of making the *telia* brick was vital to the success of future repair and conservation work.

The fact that the brick is called *telia*, which means oiled, led us astray during our first experiments. We are unable to find any practical information about the manufacture of these bricks and had to resort to direct experimentation. These initial efforts were made in the traditional brick fields and, although it was unlikely that we should produce a brick resembling in any way the original model, we were able to draw quite a crowd. Having covered ourselves in mud and oil, much to the enjoyment of the onlookers, a voice from the back soon called out that we were not making the bricks correctly. The old man who had called out disappeared to collect his tools and then returned to show us where we had gone wrong. A

The stages of making the special *telia int* brick: (a) preparing the clay; (b) shaping the brick; (c) preparing the face; (d) slip glazing prior to firing [*Photo:* Unesco/J. Sanday].

second old man then pronounced this effort also incorrect. Arguments between the two men, however, led to some sort of compromise and the bricks were made and then fired. The results stood up almost perfectly to several comparative tests with the original bricks. Samples of the new bricks and the originals were paired and sent to a specialist in London for chemical analysis. The report was barely able to differentiate between the two products.

Many varieties of brick were made and in each case the wedge shape was preserved. We have so far made header, stretcher and corner bricks with slip glazing on two faces. There are also many different bricks required for mouldings over windows and patterned terracottas which will need further experiments later.

After initial runs of small quantities of bricks, in which the process was perfected, an order for 10,000 bricks was placed with a local brick kiln; the bricks produced have matched up to the original samples.

The method of making the bricks is a lengthy and complicated process that may be summarized as follows.

The particular clay used for the manufacture of these bricks is of great importance. Fortunately, there is a very good clay seam running through the valley with little variation and needing no mixing with other ingredients. This clay is dug from two metres below the topsoil. It is then thoroughly prepared by trampling underfoot so as to remove any foreign matter and to make it workable. The clay is then thrown into a wooden mould which is slightly larger than the final brick size, thus permitting approximately 10 per cent shrinkage in firing. The average size of a fully burnt brick is 8 × 2 × 4 inches. The brick is turned out on a bed and left to dry for one day in the shade, after which it is firm enough to be handled. The next stage is for the brick to be shaped. The brick is squared up to a depth of two and a half inches, a suitable face is selected and flattened with a heavy mallet, causing the face to spread under impact. The brick is then trimmed with a scimitar-shaped knife and a straight edge to form the sharp arrises to its face. During this process the brick is cut to a wedge, after which the face is whetted with a small flat piece of timber or stone to achieve a uniform surface. The brick is then left to dry for five to eight days, after which the slip glazing process begins. The clay used for the glazing is taken from a special seam in a small village on the outskirts of Kathmandu called Hadegaon. The clay is excavated, cleaned of all rubbish, well kneaded and then stored beneath sheaves of paddy straw throughout the monsoon. During the rains, the straw produces a microscopic fungus growth like a fine red dust which is washed into the clay by the rain, thus giving it colour and texture. After a certain period it is stored in a godown to mature for six to ten years.

This clay has become quite a commodity, and has been much used in the glazing of pottery. The clay is mixed to a slurry and carefully applied to the face of the brick. This is then burnished with a haematite stone, which gives the brick its lustre, after which it is left to complete its drying process. The longer it is left before being subjected to the heat of the kiln, the less it is likely to crack when it undergoes violent contraction during firing.

Two types of kiln are commonly used in the manufacture of bricks in the Kathmandu Valley. These operate in quite different ways. The first and probably original type of kiln is the clamp kiln, into which the bricks are stacked together with the combustible materials, usually straw, wood or coal. Once the clamp is filled, it is lit and left to burn itself through. When the fire dies away and the bricks have cooled sufficiently, they are removed and the process is repeated. The rotational kiln is, no doubt, an imported idea. It is far more sophisticated and requires coal to fire it. Once the fire is lit, it burns for an entire season.

The kiln is generally circular with a solid core; the circle is divided into eight or more sections. The fire occupies each one of these sections for a day and is rotated by moving the tall chimney to the next bay and stoking with coal the bay beyond. At the point most distant from the fire, the newly burnt bricks are removed and the new bricks ready for firing are stacked. The process takes about a week. The main advantage of this system is that the brick is gradually heated and then gradually cooled, which prevents unnecessary twisting and warping. The rotational kiln was chosen as the more reliable method, the heat being more intense and the results less distorted.

Nowhere has there been any oil used other than in the cleaning of the brickwork with an oily rag. The name *telia* for the brick appears to be a misnomer. It is a Nepali word meaning oil, and the only explanation seems to be that the word was invented and used in a descriptive sense to describe the glaze. The glazing adds to the durability of the bricks, as well as heightening the many hues of red produced by the clay. It also makes the bricks almost entirely impervious to water. The bricks are wedge-shaped, with very sharp arrises. This means that, when laid, they can be bedded into a thick lime mortar at the back, and the front joints, which are barely a tenth of an inch thick, can be pointed in clay.

Tiles are usually made in the same brickyards and of the same clay. Again, the tradition has faded and, for the same reason as above, the technique is recorded here.

The *djigati*, or small tiles, are trimmed and pressed from a specially prepared wooden mould and are made from clay that has been prepared in a similar way to that used for brick-making.

The large ridge and hip tiles are cut from a template, usually of steel; however, to achieve the angle, or saddle, a section of ground is specially prepared, forming the raised angle over which the clay is laid. The template is then laid on top, and the clay is cut to the correct shape. The tiles are all left to dry in the sun; once they are sufficiently dry to be handled, they are set vertically so that they are not in direct sunlight and can be air dried as well.

They are also fired in the rotational kilns; there are some tile makers, however, who still prefer to use the traditional clamp kilns.

Woodcarvings, their cleaning and consolidation

Among the arts of Nepal, perhaps the best known is the woodcarving that adorns both domestic and religious buildings. This is a craft that developed in the fifteenth and sixteenth centuries during the Malla rule among the Newar tribes. Today, it is still maintained by these same tribes. However, the demand from commercial enterprise gives them little opportunity to practise their art-form.

The Kathmandu Valley is the main stronghold of Nepalese culture and contains important examples of local art. The royal palaces of the valley promoted all the local arts, and the best examples of each period of Nepalese art are found in the buildings which comprise these palace ensembles.

Windows and doors are provided with a series of unique surrounds and mouldings. Cornices are built up of basic shapes which are derived from animal heads, birds or vegetal motifs. Each of these is a unique individual element.

The Vilas Mandir, which is the major building in the Hanuman Dhoka conservation project, contains some of the finest examples of technique and artistry in its woodcarving. The lower struts of the Basantapur Tower are also particularly fine, as are the windows of both the buildings. The grille work of these windows is created by a very complicated geometric interlocking construction. Over fifteen patterns have been discovered in this group of buildings alone, as well as several simpler forms. Unfortunately, these windows have suffered badly from deterioration due to time, saturation, and distortion and loss caused by earthquakes. They have also been heavily overpainted in an effort to overcome their tawdry appearance. We are, therefore, faced not only with problems of replacement and repair, but also with the careful cleaning and conservation of the remaining examples, if this disappearing art form is to be consolidated.

Among other aims set out in the proposals of this conservation project has been the revitalizing of interest in woodcarving and the setting up of a local or family woodcarving guild. The guild could be registered with the project office as capable of producing artistic rather than commercial work. These people would be employed to carry out conservation and restoration work such as that described above, and also to work on any new religious building that might require carving. As a long-term policy, this would maintain the original woodcarving tradition and ensure skilled and willing craftsmen for conservation work. It is also hoped that such work might increase the incomes of these families.

The fitting of the lintel to the carved window [*Photo:* Unesco/J. Sanday].

The carpentry work now complete, the window is ready for carving [*Photo:* Unesco/J. Sanday].

The carved window nearing completion [*Photo:* Unesco/J. Sanday].

When the project was in its early stages, efforts were made to find suitable woodcarvers. The general opinion at that time was that there would be little hope of finding any reliable and skilled artisans. This would have meant that the future work of conservation was far from secure in Nepal, as it would have been impossible to train carvers without some traditional expertise. We were delighted to discover a reliable and competent team of traditional woodcarvers, up to forty of whom worked for us on the conservation project.

As they work, these artisans seem to relive their traditional craft, and their work becomes part of their religion. There appears to be a strict control of the type of work each man can perform, based upon experience and competence. The task of 'opening' or carving the eyes of an image of a god can be carried out by only three men in Bhaktapur. This honour is handed down from generation to generation, and is passed on to the next man only after certain religious rites have been performed.

It is fair to say that carving was a dying tradition in Nepal: the men employed in the conservation project claimed that they were able to practise their craft only one month in a year. Most of these artisans worked with the project for its duration, and their work has been improving rapidly. Their application to the work has been admirable, even though many of them have to travel seven miles to work each day.

An unusual problem in the Kathmandu Valley which faced the conservation project office and the central laboratory was that of having to clean the delicate carvings that adorned the royal palaces and temples which where under renovation. Initial impressions would lead one to believe that all traditional buildings were meant to be decorated in an assortment of paints and colours as an essential element of their impact. However, on closer inspection, the quality of the carving suggested that the concept of painting the buildings appeared much later in their historical development, and may have been used as a method for tidying them up during important regal or festive occasions. Careful research on the Hanuman Dhoka Palace soon revealed sections of exquisite carving that had been built over during subsequent additions to the palace, and these carvings had no vestiges of paint on them at all. On this evidence, therefore, a rational decision could be made to clean the vast area of carved windows, doors and other decorative elements and to expose the delicate detail that was hidden by the caked paint.

Before the method of cleaning is described, it should be explained that the use of colour has religious significance, each deity being easily recognized by his own particular colour. It is important therefore that each case of cleaning should be assessed on its individual merit; a few successes do not establish a precedent that all buildings should be cleaned of their colouring as a matter of course.

Once it has been established that the paint should be removed from the carvings, tests should be carried out to ascertain the type of wood and its condition, as well as the type of paint or colouring used and if possible the number of coats. This work is best done by a specialist from the central laboratory.

It will be found that most of the colouring, especially the reds, blues and yellows, is a water-based powder mixed with flour and sometimes glue; whereas the black colouring is a mixture of soot from the kitchen chimney, again mixed with glue. The glue is made by boiling buffalo skin for several hours in water until it becomes a glutinous substance. The introduction of oil paints now represents a threat, as this type of covering will require special chemicals to remove the paint.

An important principle when cleaning timber is to minimize the amount of water used. For this reason, the process is divided into three basic operations:

1. *Dry cleaning.* The first lengthy and laborious operation is to remove as much of the coloured coating as possible by mechanical means. This is done with a small blunt scalpel held between forefinger and thumb. The scraping is done so as to avoid damaging the timber which, if it is salwood, is very resistant. Once all the debris is removed by brushing, the piece is ready for the second operation. If the timber is too soft for this type of treatment or has been damaged by beetle or fungal attack, it will be necessary to omit cleaning by scalpel, and after only light brushing move on to the next operation.
2. *Wet cleaning.* After the lengthy process of dry cleaning, the wet cleaning is very rapid. For this reason it is advisable to prepare several pieces for wet cleaning at once. This process is very simple, but speed is of the essence. A dilute mixture of ammonia and water (about 1:8) is prepared in a small bowl. This is brushed over the wood with a stiff-bristle scrubbing-brush which will loosen the remaining traces of colouring. It is then sprayed off by pressure spray and, if the colouring still persists, the process should be repeated once the piece is dry.
3. *Clay poultice.* For delicate carvings or damaged timbers that will not withstand scraping, it is advisable to use a clay poultice made of finely powdered clay mixed with ammonia diluted (1:5) with water. The poultice should be mixed to a stiff paste and then applied to cover all parts of the carving. The poultice should be left for several hours to enable the dilute ammonia to soften the paint, after which the poultice is carefully scraped off and the carving then washed down with a pressure spray and scrubbed with a soft brush. If the paint still persists, then the process should be repeated once the piece has dried.

Removal of oil-based paints

Where oil-based paints have been applied it is necessary to use one of the proprietary paint removers. One product that was successfully tested was water-soluble Nitramors—this caused no discoloration or ill effects to the timber.

Damaged or weak timbers that require consolidation can be treated with products such as Bedacryl or resin fillers. But the use of such chemicals should be discussed with the central laboratory.

Should any of the carvings require consolidation, it is best for the treatment to be carried out after they have been immersed in the chemical bath. As a precautionary measure, it is advisable to treat all the carvings as a matter of course against beetle infestation and fungal decay. The most economical way of doing this is to make a large bath into which the fluid is put. The elements requiring treatment can then be totally immersed in the chemical, giving them overall protection. The chemical used was Wykamol Plus.

The timber treatment bath [*Photo:* Unesco/ J. Sanday].

Annotation and the repair of carved elements

The vast quantity of carving to be found on any building in the Kathmandu Valley necessitated the conception of a foolproof method of recording every individual carved element. When one considers that the number of single carved elements that were handled in the first stage of the Hanuman Dhoka project numbered well over 15,000, the importance of such a system becomes obvious.

It was soon discovered that, owing to the nature of construction, the carved elements could easily be dismantled. Once dismantled, they could be stored away from the debris; this lessened their chances of being damaged. They could also be worked on systematically in both the cleaning section and the wood-carvers' studios.

Prior to their dismantling, the carvings were carefully referenced using a plastic embossing tape tacked on to each single item. This tape bore letters and numbers (e.g. AWN/15/23) relating to:

The building or section of building they came from	A
The building element—window, door or strut	W
The elevation—north, south, east or west	N
The window or door number	15
The actual piece number	23

As they are available, different colours of type can be used to make the various elements easily recognizable.

The actual piece number for all similar pieces (e.g. cills) should be the same throughout.

The tape was found durable and withstood immersion in the chemical bath.

Once the carvings have been referenced and cleaned, they should then be examined to assess the repair that may be necessary. In many cases, where a piece of carving has been badly disfigured, it is advisable to replace it completely as there may still be sufficient evidence and detail to reproduce the piece exactly. In many cases, if a partially damaged piece is not replaced in a building, its rate of decay may be much faster than the adjacent pieces; this will not only affect their lifespan, but will also start the deterioration of the façade as a whole. When skilled and traditional craftsmen are available in such profusion, and when they are working in the same style and manner as did their forefathers, it seems logical to maintain the fine detail and sharpness of line originally intended in the carvings.

The principle that has been adopted in the work carried out so far is to replace any defaced or worn sections of repetitive carving such as floral motifs as a complete piece. If a piece is missing, and is easily identifiable, this too can be replaced. If the defaced or damaged piece is an individual item that can be classified as a work of art, it should be consolidated and preserved in the condition in which it was found. Adding new arms and symbols for deities to individual elements has been avoided.

If, however, a complete series of supporting struts have been lost, their absence is very noticeable and has an overall effect on the unity of the façade. In such cases, these struts have been recarved following the true tradition, and placed in the building as an example of the capabilities of twentieth-century craftsmen. The woodcarving tradition still survives and therefore must be recorded. Nevertheless, each new piece should be dated or marked in some way to show that it is an addition to the original.

The practical aspects of repairing individual pieces of carving are best discussed with the craftsmen themselves; bearing in mind that, if the carving is sound and the joints or the backing timber are defective, every effort must be made to save the carved piece. Defective tongues or tenons can be cut out and replaced by dowelling and gluing in new ones; carved elements can be cut off and refixed in the same way onto a new backing timber. A resin-bonded glue is best used for its reliability and strength, along with dowels of bamboo. Wherever possible, avoid using metal fixings, as traditionally they were never used. Screws should only be used under supervision, and should be properly countersunk and plugged.

MIXED TECHNOLOGIES

Brickwork and its repair

Brickwork collapses from mechanical failure due to the effects of changes in the loading. This can be caused by dilapidation in a part of the timber structure which has succumbed to beetle and fungal attack, or excessive movement caused by earth tremors and the like. Chemical attack by salts at the base of the building can cause severe erosion of the fabric.

Once the cause of failure has been established (after a thorough survey and an evaluation of the structural loading have been made), the task of strengthening the structure or redistributing of the loading can be carried out. This may be achieved either by reinforced concrete poured *in situ* or, if failure is due only to movement and no heavy loading is involved, by careful bonding of new brickwork set in a stronger mortar. Techniques involving the use of concrete are described under the section dealing specifically with the use of concrete in conservation. In cases where the failure in the bonding of the brickwork is fairly localized, it is possible to remove a section and insert a concrete bonder across the fracture, casting it *in situ* and then rebuilding the wall to conceal the concrete.

Rising damp can cause major disruption to the base of a wall, because the dampness which is drawn up through the brickwork by capillary attraction will bring with it harmful salts from the earth. These come to the surface of the brick as it dries out. They then crystallize, during which process they pull off the outer surface of the brick. This is especially damaging if they are special glazed bricks, and in severe cases can contribute to the structural failure of a wall. This defect, generally referred to as 'efflorescence', is extremely common in Nepal as none of the early buildings has any form of damp-proof element to prevent moisture rising. The condition is accelerated by the climatic conditions of rainy periods followed by long dry periods, during which time the salts crystallize. Most of the buildings are built on platforms to minimize the effect of rising damp and the ground floor is used only as a storage area. There are today simple techniques to prevent rising damp which entail putting an impervious layer into the wall. Perhaps the most suitable for the conditions in Nepal is the silicone-injection method. The principle is to inject into the wall base, either by gravity or under pressure, a silicone mixture designed to percolate the thickness of the wall and to produce a barrier about two brick courses deep. The silicone coats the particles making up the bricks, making them impervious to moisture. The walls must be of dense construction, otherwise the silicone, taking the line of least resistance, will run through the gaps. Although research was carried out as to the feasibility of this method, it was not employed during the Hanuman Dhoka conservation project.

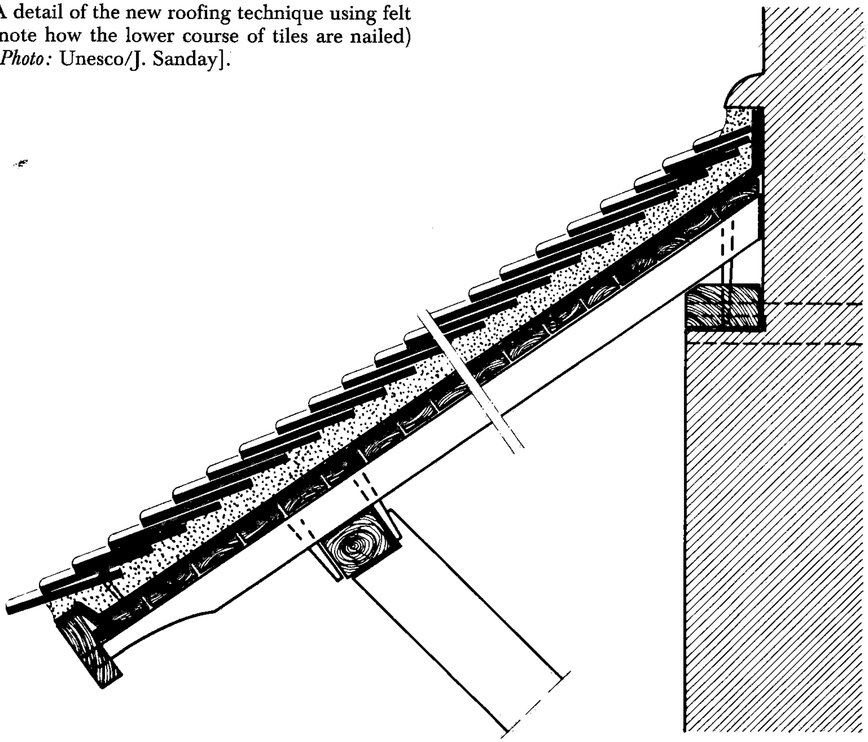
Should it be necessary to dismantle a wall during a repair programme, then a damp-proof film can be inserted. This should be done at approximately 15–20 cm above ground level. The best material to use is a coarse-grade polythene—unless, of course, a proprietary DPC is available. It should be remembered that concrete and cement are not entirely impervious to water and are liable to crack.

Efflorescence in brickwork should be removed by repeated brushing with a stiff dry bristle brush over a period of time. On no account dampen the brickwork, as this will drive the salts back into the wall. The wall can be finally polished with a clean, oiled rag to bring out its true lustre.

Roof coverings

The most obvious failing in the fabric of the traditional Newari structure in the Kathmandu Valley is that of the roof covering. The very nature of their construction makes the roofs extremely vulnerable to the prevailing weather conditions. Probably, when these buildings were originally constructed, great care was taken in the selection of materials, the tiles were well burnt, the clay bed was carefully selected and the timber of prime quality. However, deterioration due to old age has resulted in the need for replacement, or earthquakes have necessitated extensive rebuilding. The care in the selection of materials during rebuilding was not up to former standards, and as a result water has penetrated the tiles to

A detail of the new roofing technique using felt (note how the lower course of tiles are nailed) [*Photo:* Unesco/J. Sanday].



germinate seeds in the unsterile mud. Vegetational growth begins with a few shoots that bear seeds, after which propagation in earnest results. It is also common for birds such as pigeons to deposit seeds in their droppings and for these to germinate in the same way.

Each year the condition of the roofs will worsen, with the growth attracting more moisture; this in turn saturates the structural timbers below, causing fungal attack. In the most severe cases, the added weight of the vegetable growth, together with the moisture and the weakening effect of the fungal attack, will cause the roof to collapse. In the multi-roofed structures, the collapse of one of the upper roofs will usually result in the structural failure of the roofs below.

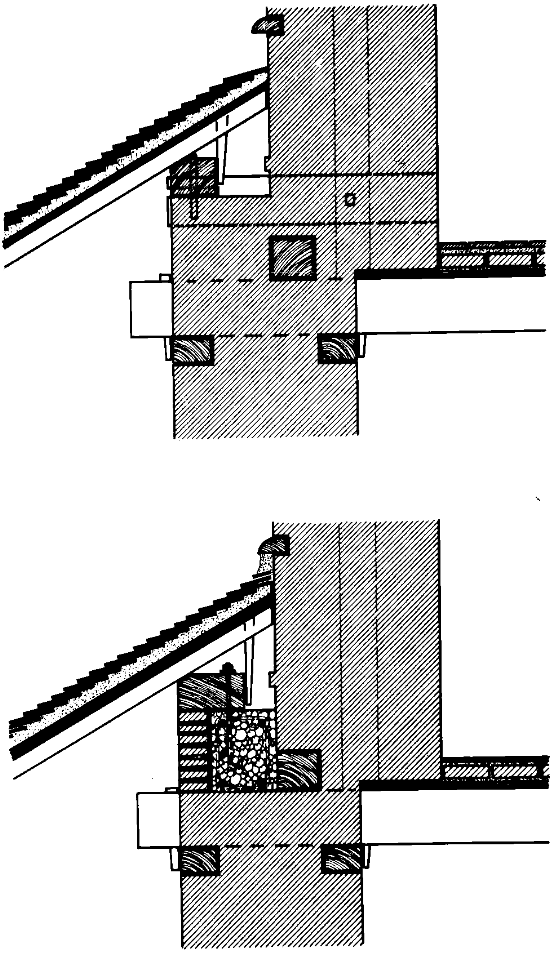
To protect these roofs it is necessary to create three barriers: to prevent water penetrating through the tiles; to prevent the germination of the seeds, both those already present in the clay base and those that are airborne or carried by birds; and finally to prevent the moisture reaching the timber structure. The following methods were evolved with this in mind.

The clay base should be sterile and dug, as in the past, from a minimum depth of one metre; the clay selected should be one that is traditionally chosen for this application. The *djigati* tiles should be well burnt or, if they are to be re-used, thoroughly cleaned of any mud or lichen. The timber should be treated as previously described before laying.

The first barrier is a double layer of bituminous felt over the boarding; this should be nailed in position with clout nails and not, as in common practice, stuck on with hot bitumen. In liquid form, the bitumen will run between the joints of the boarding, spoiling the timbers and carved struts below. The second layer of felt should be stuck over the first layer with hot bitumen, after which staggered timber battens should be laid to give a key for the clay bed. The final coating of bitumen can then be laid over the battens as well, after which the coating should be blinded with sand.

The following two stages run together and should follow the previous stage without any delay. The second barrier, which is incorporated in the clay, is a powerful herbicide sprayed over the bed prior to the tiles being placed. The most suitable chemical is Karmex, which is added to water according to the recommended dosage and sprayed freely over the bed immediately prior to laying the tiles. (Karmex is obtained in powder form in kilogram packs from India, where it is used extensively for crop treatment.)

The tiles themselves form the third barrier. The clay is initially porous. However, after several years' exposure to the elements, dust and lichens, the tiles lose their porosity and become more waterproof. It was therefore decided to treat the tiles with silicone to make them non-porous. The tiles were immersed in a bath of dilute silicone (1:20 or 1:24) for a period of about thirty minutes, but this can be gauged by testing saturation time for the tiles. (The silicone preparation used was Sil-



A concrete 'L' beam to carry both the skirt roofs and the terraces [*Photo:* Unesco/J. Sanday].

Laying the Djingathi roof tiles [*Photo:* Unesco/ J. Sanday].

treet, at one time available in Kathmandu. It is made under licence in India and can be ordered in bulk at reduced rates.) The tiles should be drained dry before being laid, and the residue can be returned to the bath. The operatives should wear protective gloves when handling the wet tiles.

The vertical ridge and hip tiles should not be treated with silicone. They are designed to soak up the rainwater and evaporate it off before it percolates to the roof below. This they do very effectively.

So far, this method has proved to be very successful. Over a period of almost five years no vegetation has appeared on any of the roofs treated in this way.

A few innovations were introduced when laying the tiles. The traditional method of pressing the tiles into the clay, ensuring a triple overlap, was followed; but the lowest course of tiles, the ones most likely to be lifted off the roof by the action of birds, monkeys or high winds, were drilled and nailed to the fascia board with stout galvanized nails. These nails had to be specially adapted from a type of bolt available in the local market. Although the idea of nailing the tiles was prompted by concern for the safety of passers-by, it was learnt subsequently that similar tiles with holes in them had been excavated from a much earlier historical site.

A special metal support, one metre long, with a turned-up end a little less than the depth of the vertical tile, was firmly fixed at the eaves end of the hip to give the necessary support to the very heavy vertical hip tiles that stay in position by friction.

Although copper roof coverings are restricted to some of the more prestigious buildings, their condition does not always match their importance. Experience gained from the repair of the Kirtipur Tower in the Hanuman Dhoka project highlighted the inherent failures of both the materials and the methods of application. The Kirtipur Tower has a dome-shaped roof that was covered in sheets of copper measuring approximately 30 cm in depth and 110 cm in width. The sheets were set against ribs along the short edges running vertically up the roof, which were capped. The horizontal joints were a simple overlap of about 3.5 cm, and sheets were fixed to the base board by nailing straight through both the sheets along the joints at intervals of about three sheets. At the remaining joints the sheets were riveted and only nailed down along the vertical short edges. Rainwater found its way directly through the nail-holes and it was both blown and, by capillary attraction, percolated between the joints. During its life the copper sheeting became loose because the timber had rotted around the nails, and a heavier nail had been driven in place of the old to secure the sheets again. The compound effect of the heavy moisture penetration and the disturbance caused by earthquakes resulted in the need for almost total rebuilding of the structure and of course a new roof covering. Before condemning the original covering as being unsuitable for re-use, considerable research was carried out into the prospects of reconstituting the copper. However, the sheets were too brittle and the copper of very poor quality. They are now being kept for archaeological reasons. New sheets were therefore imported, and it was possible to obtain the best possible grade of roofing copper, namely, fully annealed copper of a dead soft temper. With this specification, it was possible to work the sheets to the special shapes required on the complicated roof plan.

The major problem was to achieve a sound and leak-proof joint between the sheets, and to obtain suitable fixings without puncturing the covering. It became necessary to train a team of coppersmiths in the technique of forming welts and rolls for joining the copper. The horizontal joints were formed with a double-lock cross-welt, and the fixings were copper tabs incorporated or folded in with the welt. The vertical joints are formed against rolls, the copper sheets being dressed up against the roll and then capped with a copper capping. In this way the roof is well fixed to the boarding without perforation and the joints are watertight.

One other problem that is fairly common with copper roofing and in particular with sheets with a dead soft temper is that, being very malleable, they will take on the form of the boarding below. The copper will also 'flutter' if the wind gets under the sheets, and the continual knocking against the boarding will wear it out; flexing may also cause the copper to 'work harden'. It is therefore advisable to lay a layer of felt (e.g. carpet underlay) underneath the copper to serve as a cushion.

It should be remembered that all fixings on a roof to be covered in copper must also always be of copper, as contact with any other metals such as steel nails would create electrolytic action and decay.

Stone conservation and repair

As already mentioned, the quality and quantity of stone available is limited. Often the buildings will be of an odd mixture of different stones, and usually the stones will be laid on the wrong bed. There are, however, a few exceptional examples of sculptured stone buildings with specific problems in need of conservation, but in each case it will be necessary to give specialized and individual treatment.

In buildings there are many stones that have fractured or have had a section such as a corner (or, in the case of sculptures on some of the buildings, an arm or a head) broken off. These types of repair can be easily carried out today by using specially developed adhesives which, like the timber glues, are immensely strong. It is also good practice to fix damaged stones, or pieces of stone, by dowelling them, using a short length of stainless-steel or bronze dowel; never use non-stainless ferrous metals as these will rust and eventually explode the stonework. Resin-bonded glues consisting of an adhesive and a hardener such as Akeme are best imported to ensure a good quality although 'Araldite' is available in India.

Stone buildings are prone to destruction by vegetal growth, in particular the pipal tree (*Ficus religiosa*) which takes root on or between the joints of bricks or stone having a high moisture content, and then proceeds to grow and extend into the structure slowly tearing it asunder as it penetrates through the foundations in search of life-giving moisture. As the roots expand, so the joints in the stonework open up, allowing greater water penetration and accelerating the tree's growth. The pressure created on the stonework will cause individual stones to split and the foundations or bed of the stones to be distorted. To repair such a structure it is important first to remove the growth, which may entail dismantling a considerable amount of stonework. Any sections of the growth that cannot be removed without major demolition should be poisoned with such herbicides as Bromacil or Diuron, which are injected into the trunk of the tree. This work is best carried out by the central conservation laboratory as the application of the chemicals is a rather specialized task. This type of work should only be done by trained staff.

The damaged stones can be repaired by cementing. When the stones are reset they should be cramped together using non-ferrous cramps in place of any iron cramps previously used.

In most cases, the cleaning of stone is at present a simple process. The unpolluted atmosphere means that there is little chemical attack on the stonework and the major part of the cleaning necessary consists in removing caked dirt and dust. This type of work is best done with hard-bristle brushes; never use wire brushes as these will damage the patina as well as the surface of the stone. Any more stubborn surface growths should be scraped off using bamboo spatulas. Avoid using water if possible as this will disperse any harmful salts back into the stone. Cleaning can also be carried out with dilute alcohol. Advice should be sought from the laboratory if this method is used.

It should be remembered that the treatment of stone is a very specialized subject, that the stone buildings in the Kathmandu Valley are not very plentiful, and that not much research has yet been carried out in this field. Therefore, before commencing any work on a stone building, specialist advice should be sought.

Reinforced concrete

The use of this most 'modern' of materials in the repair of historic buildings is often frowned upon by many people, who in fact forget that it was used extensively by the Romans. All the same, concrete should not be used indiscriminately, as it is a material that is out of character in the traditional buildings of the Kathmandu Valley. Nevertheless, there are instances in the consolidation of an old and failing structure where the use of concrete with all its properties is indispensable. Ring beams, bonders, supporting beams and wall plates were all cast into the structure of the recently renovated Hanuman Dhoka; the Masan Chok in the Kathmandu Durbar Square was consolidated in its leaning state, and the Shiva Parvati temple opposite was capped with a ring beam to strengthen the walls, which were spreading as a result of the heavy roof load. In none of these cases is the concrete visible.

The advantage of using concrete is that it can replace timber in areas where it has rotted. In many such cases the concrete will also act as a water barrier and prevent water percolating through the structure. It can replace timber almost section for section, and ensure a stronger and more stable support. In tension, concrete can be used to prevent the upper sections of high buildings from bulging outwards. It should be remembered that concrete has approximately twice the density of salwood, and this should be taken into consideration when designing the new structure.

The purpose of a ring beam is to consolidate the uppermost part of a wall that is being distorted by the dead load produced from the roof. It also gives a sound and level base for the roof. The beam should be designed to take the horizontal thrust from the roof and if possible should be well keyed to the wall it is set on. In most traditional buildings there is a series of posts forming the inner timber structure, and the beam can be cast around these, replacing the original timber beam or lintel. To fit the beam, a section of the wall should be dismantled, the external brickwork being built up to form the shuttering for the beam. The timber wall plates to support the ceiling joist and rafters can be placed over the concrete and should be bolted into it, the bolts having been placed into the concrete before it sets. The shape of the ring beam can be varied to suit the situation, but the tensile strength must always be maintained, and the beams must be continuous.

Concrete beams can replace timber under exposed terraces where it has rotted as a result of continual water percolation. In such cases it is possible to take the timber out without disturbing the structure above, having first shored the upper part; the steel can then be threaded in and the concrete poured into specially designed shuttering. After the concrete has set solidly, the structure should be consolidated onto its new base, after which the shoring can be removed.

A defective structure can be strengthened at any level in the building by using an ingenious method of underpinning. This kind of work should only be carried out by experienced supervisors and craftsmen, as strict supervision and careful monitoring of the building are essential. The process is to stand the structure on a series of iron stools by first cutting pockets at the required level. The stools are solidly bedded in these pockets, which are spaced at intervals of one metre along the wall. Once the rich cement grouting on which the stools are bedded has set, it is then possible to remove the brickwork between the stools. Theoretically, the structure is now supported by the stools, but in practice there is generally some remaining brickwork in the depth of the wall which gives added support. The required steel is then threaded between the stools, after which the shuttering is built across the opening with the upper lip of the shuttering projecting higher than the opening; when the concrete is poured its level will rise hard under the structure above. The concrete should be well tamped to prevent cavities, and it is advisable to have a wetter mix than normal. Once the concrete is set, the shuttering is removed and the face bricks are built up over the concrete to conceal the beam.

In very severe cases of structural disruption, it is possible to build in a supporting concrete structure. This will overcome the need to dismantle and rebuild a building that has become characteristically out of 'true' with age.

CASE-STUDIES OF TECHNOLOGY APPLICATIONS ON CONSERVATION SITES

The Hanuman Dhoka Conservation Project

The main purpose of the Hanuman Dhoka project was to establish a training programme for the Nepalese administrative staff, by giving them experience in working on a major restoration project, which would be supplemented by fellowships for training abroad. Its purpose was also to form a skilled team of competent craftsmen as a basic workforce to form part of the department responsible for the conservation of this heritage.

The repair work was divided into three separate stages; in part this was due to the limited budget available. The first priority stemmed from the fact that, traditionally, the kings of the present dynasty are crowned in the Nassal Chowk, the largest courtyard of Hanuman Dhoka Palace, and that the coronation of His Majesty King Birendra Bir Biram Shah Dev was planned for 24 February 1975.

Stage 1 of the project was completed by the end of December 1974 and involved the work of repairing and reconstructing the complex of buildings making up the Nassal Chowk. The work was supervised by the Unesco/UNDP expert and carried out with a limited budget, with a generous contribution from Japan and other donations from France, Pisa (Italy) and the Britain Nepal Society. Part of the local costs were met by a special subsidy from the palace.

Stage 2 of the project involved the straightening of the leaning Lalitpur Tower and the repair of the octagonal Bhaktapur Tower. The section of the Vilas Mandir between these two towers, on the eastern side of the complex, was also repaired. Work started on this stage in September 1975, most of the funds being provided by the Federal Republic of Germany. Extensive damage caused by the 1934 earthquake, not previously anticipated, was uncovered in the early stages and as a result further funds had to be provided by both the Nepalese Government and Unesco.

Stage 3 is the most ambitious and will involve the complete repair, renovation and rehabilitation of the Vilas Mandir to complete the repair programme. The building is to be converted into a museum and thus open to visitors.

The early history of the Kathmandu palace complex, now known as the Hanuman Dhoka Royal Palace, is obscure. No inscriptions have yet been found which date from before the rule of Prithvinarayan Shah in the second half of the eighteenth century, though traditions concerning the palace go back further in time. Almost certainly, the Mallas who ruled in Kathmandu from the fifteenth century had built themselves a royal palace, but it is not known what portions of the existing complex, if any, were standing when Prithvinarayan Shah came to the throne. The true history of the buildings of the palace, therefore, is still to be established. Significantly, repair work associated with the conservation project is revealing evidence that certain portions of the complex are early foundations, perhaps dating from the Malla period.

Prior to the reign of Prithvinarayan Shah, the Kathmandu Valley was divided into three separate kingdoms with their capitals at Lalitpur, Bhaktapur, and Kantipur. These capitals correspond to the towns now known as Patan, Bhadgaon and Kathmandu respectively. In 1770, Prithvinarayan Shah commemorated his victory in the valley by constructing the tower known as the Basantapur Tower. This now forms one of the most prominent features of the palace. It is possible that Prithvinarayan Shah may have utilized an earlier towerlike structure, the upper storeys being added under the direction of his son. Further additions at the time of Prithvinarayan Shah include three other towers named Lalitpur, Bhaktapur and Kirtipur after the cities which were conquered and which contributed to the cost of their construction. Together with the Basantapur Tower, they were linked with a building known as the Vilas Mandir, or House of Enjoyment, so as to enclose a courtyard, the Lohan Chowk. The Vilas Mandir, part of which was also constructed under the direction of Prithvinarayan Shah, exhibits some of the finest timber-work in the palace. The Lohan Chowk is one of fourteen courtyards which make up the entire Hanuman Dhoka Palace. The Conservation Project was concerned with the Lohan Chowk, the four towers and part of the courtyard known as the Nassal Chowk. This courtyard is of great importance for a variety of political, religious and administrative reasons. Nassal, or Natyashwar, is a dancing god who is worshipped daily by those who desire to be initiated into the art of making and playing musical instruments. The dais in the centre of this courtyard is used during coronations, and upon it a throne is placed facing towards the east. It was in this courtyard that the ceremonies of the coronation of His Majesty King Birendra Bir Bikram Shah Dev took place. The Nassal and Lohan Chowks are linked by an elaborate and large wooden gateway.

The Kirtipur Tower

The repair work carried out on this tower as part of Stage 1 of the project was among the most interesting. This small tower has a Bengali-style roof which is covered with copper roofing that was originally gilded. In all aspects this structure is unique in Nepal, and presented many difficulties when it came to rectifying its faults. The tower was in a state of near collapse when first inspected, due mainly to the failure of the roofing. The copper sheeting had been nailed direct to the boarding and rainwater was able to penetrate the nail holes. On either side of the ridge of the roof, where the curve is flatter, water had crept up the overlapping joints by means of capillary action and caused the boarding to rot, the nails to loosen and the copper sheets to become unfixed. The general rotten condition of the timbers caused a further weakening of the structure and, as a result of several earth tremors, the timber joints had failed completely.

Thus, the team was faced with a structure that was insecure and in which 80 per cent of the timbers were not re-usable. Moreover, there was not a single piece of straight timber in the entire tower. Once it had been decided that the tower had to be completely dismantled, it was evident that very careful records and drawings would be needed to help reassemble it correctly. Every piece of carving was referenced and handed over to one of the carving sections. Each structural member was carefully dimantled, similarly recorded and handed over to the carpenters. As every piece of the roof structure was curved, and as many sections were completely rotten, the first task was to gather pieces that made up at least one quarter of the roof shape so that we could copy exactly and make mirror images of the other missing sections. In this way the structure was reassembled and temporarily re-erected to ensure that the pieces fitted together. Perhaps the most arduous task was the preparation of the rafters, which were all curved and which all had to be replaced. Again, one quarter consisting of twenty-five rafters was assembled. It was particularly difficult to determine the original complete rafters, as most of these were damaged. The pit sawyers were persuaded to cut the timbers on a curve, something they had never done before, and in some cases it was possible to cut two rafters from one baulk of timber. Thus, there could be some saving of timber.

While the carpenters were working on the repair and replacement of the structure, the carvers were repairing and replacing the damaged sections of carvings. The preparatory work took nearly nine months, and about four additional months were required for the careful fitting together of all the pieces of this major jig-saw. As a protection against further decay to the timbers each piece was dipped in a chemical bath filled with fungicide and insecticide and left submerged for about two hours.

This repair work was carried out so as to reproduce faithfully the original pieces, even down to the metal fixings, which were hand-forged in the original manner.

The Basantapur Tower

The Basantapur Tower, rising 30.5 metres from the ground, posed a totally different set of problems. Its sheer size was extremely daunting, especially the problem of having to scaffold it. At first the idea of bamboo as opposed to solid tubular steel scaffolding caused considerable concern. The work involved cutting and transporting the bamboo from the forests, erecting the many pieces and tying them together with many thousands of metres of rope. Despite all these difficulties, and after initial training of the scaffolders to tie safety knots for the lashings and to observe basic principles of safety, a team of twenty to thirty men set to work on the task. The scaffolding became the focus of speculation in Kathmandu for some time as there was little visible progress in its erection for several months. The topmost roof required major structural repair since it had been damaged during the 1934 earthquake. A new structural base to the roof was inserted, replacing the old decayed and damaged timbers. The pinnacle and its base measured 4.5 metres long by 1.5 metres wide and stood 3 metres above the roof. This had to be dismantled and lowered to the ground by means of a home-made block and tackle. It was then repaired and re-erected. The roofs were totally replaced with new timbers and the traditional interlocking joints were rationalized. Previously, they had caused inherent weaknesses in their structure. In addition, all the timbers were treated against further beetle and fungal attack.

The Lalitpur Tower

The repair programme on the Lalitpur Tower posed some of the most interesting technical problems so far encountered. Unlike the two towers in Stage 1, where the problems of repair and renovation were not clearly visible, the failings of the Lalitpur Tower were a major attraction, visible from along the main street (Juddha Sadak). Its notorious tilt of over fifteen degrees from vertical was caused by the 1934 earthquake; the reason why it had not collapsed in the meantime was that, shortly after it had been damaged some engineers, reputedly from Germany, propped the building in its leaning condition to prevent it from total collapse. It survived thus for just over forty years to become a challenging subject for renovation by the conservation project office.

Initial careful examination of the

structure showed that the actual breaking point of the lean was where the solid brick walling ended and the flexible timber framework took over. This framework, consisting of an unbraced post-and-lintel structure supporting a very heavy roof, was also supporting externally complete façades of carved windows. The reason for failure was, first, that the structure lacked any diagonal bracing; but, due to its high flexibility, all the failure was at the joints. Apart from a few warped or twisted members, almost all the structural and decoratively carved timbers were reusable. The roof, being a hipped structure, well designed and built, but of very heavy construction, was responsible for the sideways movement. In fact, it had slid across; the eaves were still parallel with the floor after the earthquake and the tiles reputedly remained on the roof.

Because of the flexibility of the structure and the excellent condition of the roof, it was hoped, originally, to lighten the roof structure by taking off some of the easily removable carved work and physically jacking the building back into an upright position, as a demonstration of the many possibilities in the field of building repair. It was soon discovered, during preliminary investigations, that much of the structure supporting even the brickwork of the tower was in a very dangerous state. Also, much of the carved woodwork on the south elevation was badly weathered, due to its excessive exposure to the elements. It was necessary, therefore, to resort to carefully dismantling the building following the techniques so well tested and proved in the first stage. All the carved windows, cornices, etc., were referenced, dismantled and sent for repair to the carving section; it was soon discovered that, because of the redistribution of the loads as a result of the damage done by the earthquake, many of the timbers were badly damaged and would require very careful refitting. It was therefore decided to rebuild each individual façade in the carvers' studios off a level base, and to iron out any of the major faults before rebuilding the tower. In this way much valuable time was saved, as the re-erection of the timber structure was able to proceed with the minimum of interruption once the structural base had been repaired.

Due to the considerable movement caused by the earthquake, the structure beneath the tower had opened up enough to allow rainwater to percolate the timber supports, causing extensive structural failure almost to the point of collapse. With the judicious insertion of concrete beams and bonders within the brickwork to replace the vulnerable timber structure, and, having rebuilt the badly damaged north wall, a firm base for the upper section of the tower was formed. This base was strengthened by the insertion of a concrete ring beam with anchor points into which the base plate of the windows could be placed. Next, the inner structure was erected, both level and plumb and, to strengthen the framework and

The Lalitpur Tower—before and after renovation [*Photos:* Unesco/J. Sanday].

prevent the lateral weaknesses, diagonal bracing using specially tailored angle irons was inserted between the vertical posts and fixed horizontal members to form a kind of lattice girder around the upper part of the structure. These braces were bolted together through the vertical posts to give added rigidity, and the whole structure was hidden by brickwork.

The roof was replaced using over 90 per cent of the original structural members which had been duly referenced, only for it to be discovered, once they were cleaned, that a previous numbering system in Newari had been used. Various key joints that had become loose were strengthened with iron clamps or braces, and timbers that had been lengthened by using scarf joints were replaced where possible using a single length.

The standard repair work, cleaning

and conservation techniques which had been tested and proved to be both practicable and successful in Stage 1 were used again to complete the work on this tower and the final result is a fine tribute to the craftsmen who worked on its renovation.

The Bhaktapur Tower

Unlike the other three towers, which were in a very poor condition, the Bhaktapur Tower had withstood most of the devastations that had affected the others. In fact, the work that was carried out was basic maintenance. It was originally intended to carry out the cleaning of the roof members and the carvings *in situ*, but as the team of carpenters had by now perfected the technique of dismantling and reassembling complicated structures, and the cleaning of the long roof members was very much easier when dismantled, the rafters and internal supports were taken down, giving easier access to the carved windows which were cleaned *in situ*.

Owing to the nature of the structural plan of the tower, it being a square with the corners cut off to form an octagon at the point where the timber framework supersedes the brickwork, it suffered no major failure as a result of the earthquake. It appears that the roof and its covering as well as the carved windows remained intact, with only very local disturbance. The work carried out was therefore of a general nature and consisted in re-roofing to incorporate the new techniques evolved in Stage 1 and the cleaning and treatment of the woodwork of both the carved windows and the roof structure. The complex roof pattern was a real challenge to the traditional roof tilers, and no doubt their skills have gone a long way to enhance this very decorative and unusual tower.

The Temple of Batsala Durga

The Batsala Durga Temple stands prominently in the Bhaktapur Durbar Square adjacent to the famous Golden Gate. It is one of two stone structures and is built in the Sikhara style on a raised platform. It is flanked by the large bell used to call the faithful to prayer, and to the right of the steps leading up to the shrine is another bell with a dissonant ring. The temple is built of dressed stone of different types; each façade is surmounted by a small shrine that is capped with a gilded pinnacle and flanked in each corner by four smaller cupolas. Over the central shrine, the main spire rises above the Durbar Square and is also capped with a fine gilded pinnacle. There is an arcaded open passage beneath the four small cupolas circumscribing the shrine. Under the cupolas are some fine stone sculptures, and there are several smaller pieces set in niches or on corbelled projections around the main spire.

It is said that the structure was damaged and partially collapsed during the 1934 earthquake and was subsequently rebuilt by the local inhabitants. When the work was proposed by the Department of Archaeology, the Hanuman Dhoka conservation project office and the central laboratory were consulted and, instead of calling in a contractor, the work was carried out under their supervision.

At a casual glance, the structure seemed reasonably sound; it was only when a careful study was made that it was discovered that the whole structure had been badly disrupted by a very well established growth of the pipal tree (*Ficus religiosa*). The presence of this tree had been partly disguised by the timely removal of the green shoots and leaves that made their appearance each monsoon. The growth was obviously many years old and had travelled well into the heart of the building. Beneath the stone facing, the upper part of the structure is built of bricks bedded in mud and clay; the stonework was laid dry but the individual stones are cramped together with iron cramps, and stay in position by their own weight and by bonding.

The damage caused by the earthquake was evident during the repair work; there had been considerable subsidence within the structure itself, which had been patched up with little consideration for the problems it might cause at a later date. Much of the rebuilding at that time had been very much out of true, which produced even greater problems during the renovation work. The foreman stonemason who was employed to carry out the repairs had actually helped to rebuild the temple after the earthquake, and he admitted that the earlier repairs had been rather haphazard.

The actual repair work was divided into two phases: removal and chemical treatment of the growth, and repair of the stonework. During the rebuilding, some of the former errors were corrected and consideration was given to the prevention of rainwater percolation.

The growth had caused severe disruption to much of the stonework. The line of the cornice had been distorted by the roots growing between it; two of the cupolas had subsided into the structure as a result of rainwater washing away the clay sub-base above the arcade, and various pieces of stone had been badly fractured due to the pressure exerted by the growing tree. It appears that the preliminary growth started at the level of the smaller shrines. The seeds of this tree are deposited by birds in their droppings. (It is said that the seeds actually germinate in the birds' stomachs.) Once the trees have established themselves, growth is very rapid and their need for water necessitates a very extensive root pattern which probes through the structure. In this particular case, the roots were found right at the base of the building, and a growth was also found at the very top of the spire, though it was not certain that all these growths were linked.

The stones were referenced and carefully dismantled in order to trace and cut out the roots. The actual dismantling was more extensive than anticipated and two of the cupolas were removed as the root pattern extended below them into the main body of the spire. The tower could not be dismantled to any great extent lest its stability be impaired, although after judicious propping and wedging, sizeable holes were tunnelled into it to take out as much of the major growths as possible. These probes were made at various levels to establish the full extent of the root pattern.

The treatment of the roots with a suitable poison then followed. A powerful arsenic-based fluid was injected into the cross-section of each exposed root. The poison circulates in the sap of the tree and, in theory, one successful dose is sufficient to kill off the entire growth. As it was not certain how many separate growths there were, all roots uncovered were dosed as a precaution.

The treatment completed, the rebuilding commenced. The first step was to consolidate the base of the shrines and cupolas. One of the lintels supporting this upper level had fractured and had to be replaced with new stone. An attempt was made to shed the water from this upper level by laying the stonework to a fall and by laying it on a weak screed over a polythene water barrier. The stones were repositioned according to their reference numbers but this time they were set in a lime mortar, as a protection against further vegetation growth. The iron cramps were replaced with cast brass cramps.

While this work was going on, various cosmetic activities were also taking place. The stonework was cleaned of its lichen growth, missing wind bells were replaced with new ones cast in the traditional way, and the gilded copper pinnacles were cleaned and repaired.

Time and funds restricted the extent of the work possible. To complete the renovation programme, the remaining two façades require further stabilizing; moreover, it is not altogether certain that all the growth has been completely killed. The stepped platform also requires resetting and tabling, as most of the rainwater caught on the platform percolates through to the foundations, where there are signs of subsidence.

This was one of the first stone buildings to be renovated under the Unesco programme, albeit a rather small undertaking. Nevertheless, it was a useful experience and it is certain that the building has benefited both structurally and visually from the undertaking.

Masan Chowk—a building on the point of collapse

The buildings that enclose the courtyard known as Masan Chowk belong to part of the original Malla Palace and consist of some of the earliest parts. Some of the carvings overlooking the main street through the Kathmandu Durbar Square, as well as the Bhagavati Temple, have perhaps the most fascinating history of any of the buildings in the Hanuman Dhoka area. First, the courtyard was named after its function, *masan* meaning cremation. It was the place where members of the Kathmandu Malla Dynasty were cremated. Another interesting point that has yet to be verified is that the palaces were usually located on the north of their city, and the *masan* courtyard was usually on the extremity of the city. Kathmandu has developed considerably to the north and even the 'old' half of the city is to the north of the present palace group.

The ornate group of windows on the north-west corner of the building, overlooking the main street, is one of the finest of its kind in the whole of the valley. It is not only beautifully carved but is made up of several beautifully carved pieces of ivory and bone, a fact only recently rediscovered when the window was painstakingly cleaned and repaired during the renovation programme.

For many years this group of buildings had been leased for shops on the ground floor while the upper floors were left empty. The temple at the southern end houses, it is said, one of King Prithvinarayan Shah's special deities and one which he brought with him to conquer the city. The presence of the shops was in conflict with the interests of the building, which had been condemned anyway as being structurally unsound. It was therefore decided to dismantle and rebuild it, as it held a key position on the coronation route. Age and the drastic effects of the 1934 earthquake had had a serious effect on the structural stability of the building and not only was the main wall overlooking the street bulging in several places but the whole structure was leaning seriously backwards. The top storey was in many places on the point of collapse, and the bearing ends of most of the floor joists and the timber lintels supporting them were in a very decayed state.

One of the more interesting and individual qualities of this building group was its undulating façade, which graphically expressed the dramatic history attached to it. The façade was a feature which harmonized well with the rest of this important streetscape.

The conservation project office seized upon this opportunity to demonstrate the need for conservation whenever possible, rather than rebuilding, and also to show the true value of incorporating reinforced concrete into an important conservation programme.

Once the main roof was removed, it was soon discovered that it was in a fairly ruinous state; it was therefore decided to take down the first level of brickwork on the main elevation, retaining the first- and ground-floor levels, and to dismantle totally the back wall, having first shored up the floor levels. The corner window, which was an extremely complicated piece of carved joinery work, was consolidated in position (it was, in fact, roped to a neighbouring tree for support), and the floor joists, which had rotted at their bearing ends, were replaced one by one. As each joist was removed, so a new one was carefully slid into position.

To consolidate the bowing and bulging wall, and to ensure a sound base for the new upper brick wall, a specially designed reinforced-concrete frame was introduced into the old wall at the front by cutting out the existing brickwork to form suitable channels or shuttering in the walls for concrete columns and by forming shuttering within the floor thickness for the beams spanning from front to back. Reinforcement was placed in these voids and the concrete was poured *in situ*, maintaining in this way the former attractive but previously rather dangerous bow in the wall. The large corner window was tied back into the structure and the windows on the upper floor were replaced in their original positions. The front wall was therefore invisibly propped from the back wall, which was solidly rebuilt in new bricks bedded in a sand-and-cement mortar.

It was possible to clean the windows of their paintwork, to remove the recent application of plaster and to repair and weatherproof the roof following the techniques developed in the Hanuman Dhoka conservation project.

The building now stands prominently in the Durbar Square of Kathmandu as a testimony of the diversity of methods possible in the field of building repair and conservation.

‘Appropriate technologies’ and restoration of historic monuments

Jacques Vérité

INTRODUCTION

Few developing countries can afford to use exclusively modern technologies for the restoration of historic monuments. It is true that for the displacement and reconstruction of the Abu Simbel temples sophisticated techniques were used, but such an accomplishment would have been impossible without international co-operation. Even during the archaeological rescue operation in Nubia, appropriate technologies were used on many building sites.[1] Computers are used in Jerash to perform the anastylosis of a temple, but the use of traditional means would probably have given the same results. Consider also the use of the computer for the study of the Amenphis IV *talatat* of Amon Temple in Karnak. This has not given better results than the patient reconstitution work achieved by the workers of the Franco-Egyptian Centre for the Karnak Temples, which enabled the partial restitution of a temple partition wall in the Luxor museum.

Site technologies have changed during the centuries according to the means available. Hence the emergence of a wide range of techniques combining ancient methods, local practices, improvisation and sometimes modern techniques. It is hard to single out those that are ‘appropriate’. Restoration-site technologies need more publicity, for work carried out remains almost unknown, is explained only rarely, and then mostly in inaccessible language. Since there is no corpus on which a chain of reasoning could be based, we intend therefore to examine technologies in the light of our own experience. The means used for the restoration of the Mustis arch in Tunisia will first be described. Some of the sites connected with the Amon temple in Karnak will then be examined. We will then be better able to explore the concept of ‘appropriate technology’ and see whether it can be applied to historic monuments.

RESTORATION OF THE MUSTIS ARCH (TUNISIA)

The Mustis archaeological site is located 120 km east of Tunis, close to the village of Krib. Krib was an important city in Roman times, and it has only been partially excavated. Nevertheless the

1. See for example the article ‘Traditional Methods and Techniques of Rescue and Reconstruction in Sudan’, *World Cultural Heritage, Information Bulletin,* No. 12, Unesco.

The Mustis Arch in 1966 [*Photo:* J. Vérité].

forum, the market, various temples and the Byzantine citadel are now visible. The town limits were marked in A.D. 238 by two arches on the road from Carthage to Theveste which crossed the town from east to west. In 1967 the Institut National d'Art et d'Archéologie (INAA), headed by Hachemi Sebaï, and more specifically the Historic Monuments Service headed by M. Fendri, decided to restore the eastern arch. The operation lasted seventeen months and was conducted by the author, then in Tunisia under a scheme by which Frenchmen perform a 'co-operation' activity abroad instead of military service. I was assisted by E. Beschaouch, the site archaeologist who is now Director of INAA.

It will be easier to understand the choice of site technologies described below if we bear in mind the fact that the Historic Monuments Service had only limited technical means at its disposal (few vehicles, cranes or hoist devices). Financial resources were also limited.

The classification of stones on the ground

After the collapse of the arch vault and the partial collapse of the south jamb, stones were lying on the ground, and it was necessary to study and classify them by the respective courses before starting work on the monument. The relatively large number of stones made it necessary to use a large classification area and implied long trips, made all the more difficult by the weight of the elements. Because the arch is located in the midst of agricultural land, i.e. on light soil, it was not possible to use the cart at the disposal of the Historic Monuments Service. Stones could be moved only by seesawing them along the ground. This would have been very tiring for the workers and would have made the classification work very time-consuming. We were forced to look for a mechanical means to perform the task, and we tried first to drag the stones with our car, but in vain. We finally solved the problem by using a tractor belonging to an agricultural co-operative which was available some days a week even though used by various farms. The stone-dragging operation around the classification area was carried out whenever the tractor was available; on other days work consisted of clearing the earth from stones at the foot of the monument and preparing them to be moved by wedging them on large pebbles to facilitate the passage of the hooking cable. An attempt to pull the stones with ropes, in order to protect them, failed and we had to use steel cables. It appeared that the stones (hard limestone) stood up to the cable and the dragging done on light soil very well, as very few of them were damaged by this removing procedure. In order to prevent any injury to workers' hands by the cable, special gloves were made in the leather market in Tunis, and although they were hardly pleasing to the eye they served the purpose perfectly well.

The dismantling of the pier

The earthquake, which most probably caused the collapse of the arch vault, produced the slippage of pier stones. No restoration could be considered on monuments in this state. The dismantling had to be done without any lever system, since the scaffolding pipes which had been ordered had not yet been delivered. By using the debris that had accumulated above ground level, a mound of earth was built against one of the faces of the south pier. The construction stones were dragged free with a crowbar used as a lever and then tipped onto the mound of earth. Their fall was reduced because the pier had already been dismantled to the level of the arch transom by previous workers who had simply thrown stones onto the ground without any protection.

The north pier was higher and its dismantling was more difficult. The same principle was used and improved to protect the lower parts of the piers against any deterioration. Beams in a vertical position were used to deflect any stone falling occasionally, and proved extremely useful on two occasions. The mound of earth was higher; not only was there material from the dismantling of the south pier but also stones taken from the foundation of the north pier (aimed at checking the shape of the foundation and its role in the collapse process) were added. The dismantling method may seem unusual in terms of professional ethics, and might be thought to show total disrespect for the monument and the materials from which it was made. But the stones stood up to the treatment very well. Thanks to this method, the work went forward on the site without any lever system.

The clearing away of earth and water problems

The boring of the foundation revealed a rubble-stone mass going down to 4.5 metres forming the substructure of the arch. But the boring done in winter when the water-table was high did not permit proper identification of the soil underneath the rubble mass. Therefore it was decided to build a concrete foundation pad connecting the two jambs. This required further excavations and thus a fresh accumulation of earth, which had to be cleared away. A stream flowed near by so it was decided to build a dam and thereby make available the water necessary for the foundations. Use of a wheelbarrow was possible but this would have been time-consuming and would have required all the human energy available at the site. Hence recourse was had to the traditional system of the area—a horse-drawn cart known as an *araba*. Depending on the carts available, two or three were used to evacuate the earth towards the stream. The dam was growing higher but water was not collecting because the dam was partially destroyed every night. We did not realize that the stream fed a garden area and that we were therefore violating the water regulations. The water problem was solved by a site worker who was willing to use 200-litre barrels mounted on wheels and pulled by a donkey to fetch water at the spring located two kilometres from the arch. From then on, a donkey and its driver were on the payroll of the project!

The rebuilding system

To understand the rebuilding system used during the restoration of the arch, one needs to know how it was initially built. Above the rubble foundation, large rough blocks of stone (approximately 130 × 50 cm) placed in quincunx supported the slabs of the arch

Water delivery [*Photo:* J. Vérité].

base. All the courses located above the base were built according to the same principle. The facing stones were of the same height for each course (but the height of each was different), the facing was carved with a chisel on its entire periphery and the central part roughly embossed. Stones were carved perpendicular to the facing in order to be less thick inside the construction than on the façade. Similarly, within each course they were wider at the level of the facing than inside the jambs. At the building stage, the trapezoidal disposition made it easy to construct a vertical joint and also to correct it if necessary, since the stones were in contact with each other for a distance of two or three centimetres only. The trapezoidal disposition in the perpendicular position of the facing made it easy to control its vertical positioning. Crowbars were used to lift the stones on their interior face and wedge them in with pebbles. The pier infill was of rough quarry stones worked sufficiently to fill the residual spaces between the facing stones and also wedged in with pebbles. Lime and sand mortar was used to wedge the first three of four courses, but above that the setting was done in dry conditions. After the setting, the facings were planed out and their verticality corrected in order to perfect the appearance of the construction. (Typical of the buildings of that period, the setting system of the time produced a real house of cards, and it is no wonder that it did not resist an earthquake.)

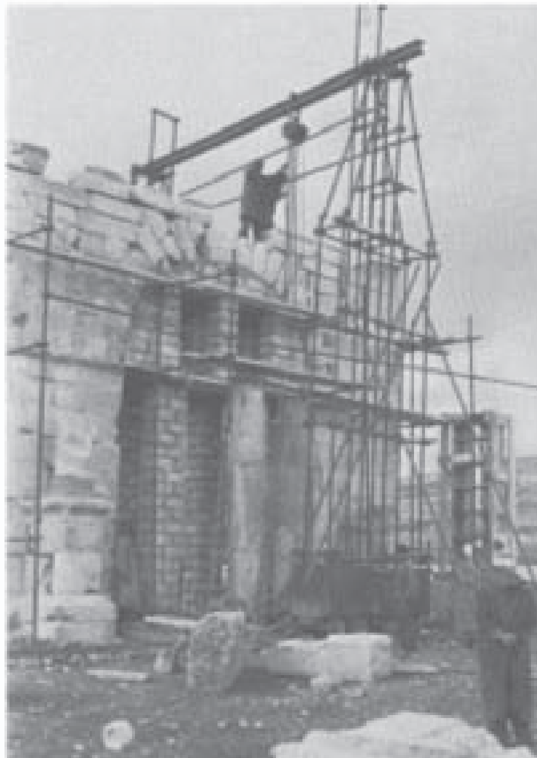
This analysis helped to establish the rebuilding principles. As was the case in ancient times, the stones were wedged on pebbles after the course was completely set in order to re-establish the initial position as closely as possible. This was not easy to find. It is difficult to secure the joints while resetting this type of large fixture, and the plumb line, as a criterion, was not sufficient to determine the position of the facings. The object of the initial resurfacing was to improve the appearance of the monument and did not aim at perfect verticality; therefore a margin of error of 2 cm on a 50 cm height was found.

The fact that the workers were unqualified was an advantage during rebuilding. Used to building their homes without measuring (even though the stones are smaller), the principle of using pebbles to wedge up the stones was not unknown to them. Adjusting the courses was mainly a question of common sense and of the external appearance, for which the plumb-line and the water-level were almost useless. One may think that a professional bricklayer would have faced more difficulties in performing this type of work, which did not correspond to the criteria to which he was used. Once the course was set all the facing joints were filled with lime-and-sand mortar. After the drying process, liquid concrete and sand mortar were poured on to a height of approximately 10 cm, the purpose of which was to see under the stones and block the pebbles used for wedging. The rough stones which formed the inside of the piers were not reset but were replaced by reinforced concrete. The steel bracings linked to the foundation pad were set across the entire top of the pier and attached to the reinforcing steel in beam form, above the arch vault.

The replacement of missing parts

On the entire building, there were few missing parts: five foundation stones, three architraves, three bases, the shaft elements of columns and four capitals. The solutions found for the replacement resembled the solution of technical and professional problems as described above. Technical problems arose from the fact that were was no stone-cutter to cut new stones to replace those that had disappeared or to even rough out the missing moulded stones. The professional problems arose because the architect wanted to make the restoration obvious. On a site like Dougga, for example, he noticed that visitors did not make any clear distinction between restored parts and ancient parts. Besides, he was irritated by articles glorifying the strength of Roman construction, and had been exposed to Swiss 'brutalism' as expressed in architectural periodicals. He decided to replace the missing parts by concrete elements. The method differed according to whether these were with or without decoration.

To replace the stones of each course, several tests were performed. The first one, made with gravel concrete in 3:8 proportion, did not seem satisfactory because it was too similar to the existing texture. By using small cofferings, we then tried to obtain lighting effects on the facings. We gave this up when it became apparent that these lighting effects were not sufficiently visible. Even after washing, the concrete was too grey, especially on the arch faces exposed to the wind where the stone had been weathered to a somewhat red colour. A permanent solution was found by using a chisel to recut the concrete facing so as to give a hollow of approximately three centimetres. The work was easily performed by the workers on the site. It yielded interesting light effects and the 3-cm hollow creat-



Reconstruction of columns—filling in with concrete [*Photo:* J. Vérité].

ed a noticeable shadow. Moreover, the concrete (after a few days of drying) resembled in form the gravel, of a colour similar to the stones. Ten years later we observed that the gravel had been weathered in the same way. While the patina was grey on the windward side, it was red on the protected face.

To replace the decorated elements, a less systematic procedure was adopted, and various constraints determined our choice. A plaster mould was made of the only surviving column base. The missing parts and the bruise flakings were carved out with a wood chisel on the plaster mould and three bases were cast in gravel concrete (3:8) carefully brushed after its withdrawal from the mould. A corbelled architrave located on a column was recast according to the same principle, but the other missing parts located on the front level were treated like ordinary stones. It was estimated that in such a case the restitution was obvious.

Only one of the shafts was complete, and enabled us to fix the height of the column. With a diameter survey every 50 cm a coffering was done in two parts. It was easy to find a carpenter in the nearest township who could cut wood sections in semi-circular shape. To get a smooth appearance after moulding, thin sheet metal was nailed between them. The base lintel and the apex astragal had been moulded in plaster and attached to the coffering. Various difficulties arose during the operation. The shafts were not perfectly circular and were not of the same size; the sheet metal showed poor resistance to the pressure of the concrete, and although it was easy to coffer the upper or lower parts of the shafts (when the coffering was used in a vertical position), it was quite different when an attempt to coat the central part was made. The work could only be carried out horizontally. Our intention was to leave the rebuilt shaft in its coffering and to lift the whole together. But the coffering did not withstand the effort and broke. The shaft fragments split and the too fresh concrete partially broke apart. To remedy the situation, the shaft was set in place and the missing parts cast with a coffering which was obviously bigger than the shaft. In none of the cases was the concrete used for rebuilding in perfect condition. It was against our advice that the surface was finished off with a chisel, giving it a rough external appearance.

All the capitals had disappeared, so, after weighing the pros and cons of the matter, it was decided to use capitals of unknown origin which we had found in the Byzantine citadel of Mustis. These capitals dated probably from the first century A.D. and differ in style from the rest of the monument, besides being slightly smaller than the original ones. No doubt the 'touristic' appeal of the monument has gained, but the solution is a controversial one, with strong arguments on both sides.

The setting gantry

After preliminary discussions it was decided that the simplest means to ensure the resetting of the stones was the construction of a rolling gantry. There is a great difference between a decision taken in an office and the reality of a site located in the countryside where very little material is available. Fortunately for the gantry, the supply of metallic scaffolding was certain (the scaffolding and the gantry required 900 m. of piping). When an iron mine was found near by, somebody had the idea of getting hold of several small waggons of the Decauville type. The director of the mine gave us four of these waggons that had not been used since 1930, as well as some old rails, most of which were bent and of a different gauge from that of the waggon wheels. Once the cross-bars were cut, the rails were straightened with a sledge hammer and attached with spikes to the beams used as cross-bars. With the help of scaffolding pipes, the waggons were attached two by two, with four pipes to each waggon, placed vertically in the waggon buckets. Braced against the wind on three sides and bound together by horizontal pipes, those eight pipes formed a kind of mobile tower which moved parallel to the arch façade at a distance enabling us to set in the columns and position scaffolding for the setting and adjustment of the foundations. The two towers still had to be linked. This was done with a second-hand electricity pole that was simply placed on the two towers. Because the bearings were so imperfect, any isostatic system (where the transversal beam is attached to the towers) could have caused the seesawing of the whole structure. The pulley-block was secured to the beam with two vertical posts and an upper cross-bar (a large bolt) that was inserted inside a piece of scaffolding tube to make it easier to move. For security reasons, and to make sure they would resist the wind, the waggons were ballasted with earth and stones, and four oblique tubes set with mobile collars were placed on the ground near by.

Setting in the stones

The stones were dragged by tractor from the classification area close to the arch. As they all had a cramp-iron hold used in the original mounting, we had a ring cramp-iron specially forged. The stone to be set was brought to the south edge of the arch in the same axis as the gantry. It was mounted with the help of the pulley moved by two or three workers perched on the construction. The gantry was then moved, pushed by two or three workers on each side, helped by two others who lifted the oblique security pipes. As the construction mounted, the rolling gantry was raised so as to allow the pulley block to be handled continuously from the rebuilt upper course. The system functioned well enough to lift stones weighing as much as two tonnes.

Lifting the concrete

With no means available to lift concrete, the usual practice in Tunisia, is to build a wooden ramp upon which workers carrying buckets can climb up. Alternatively, a series of platforms are built on which the workers use a shovel to lift the mixed concrete. The first solution would have led to the construction of a very long ramp (the concrete had to be lifted nine metres above ground level). For the second solution, a large quantity of wood would have been needed (wood is very expensive in Tunisia) and the ramp would have been extremely messy because a large quantity of grout is thrown off by the shovel. A pulley and buckets were used first. Very soon, it appeared that the system was time-consuming and tiring. Two wheelbarrows were then taken from an archaeological storeroom and, after separating the buckets from the chassis, the former were used as barrows. The weight of the buckets when full (more than 120 kg) made human traction impossible. The barrows were raised by pulley, either using a tractor or with an automobile pulling a rope set in a pulley hooked to the rolling gantry. We spent hours going back and forth in this way in our car in order to fill in each course.

Mixing concrete

It is a tiring operation to mix the different components of concrete, especially when it has to be done perfectly, i.e. without any excess water in the concrete. A 'trick' was used on the Mustis site which needs explaining. On the lower part of the shovel, a rope is hung and held by one or two labourers. Each time the filled shovel is to be lifted, the lifter is helped by those holding the rope. They lighten his task a great deal at the moment when his working position is the most difficult.

Making the soffit

We do not know how the soffit of the Mustis arch was originally made. It must have been a very difficult operation. The cleaning down of the intrados revealed a warped surface and the fact that the faces of the two keystones had been recut several times suggests that they were also wedged in with pebbles. The tracing of the archstones did not reveal the geometrical shape of the vault (although we know it was not semi-circular but flattened towards the centre). We thought that the intrados had perhaps subsided because of the load. We did not have wood or a carpenter available to make a soffit which could be modified during the setting in of the archstones. So scaffolding made with agglomerated concrete and wood was constructed in the following manner: between the ground level and the arch impost four pillars were erected, each 70 cm in width, their axes located at one quarter of the distance between the jambs. These pillars supported a beam plating on which two walls were built on the façade edge. A few centi-

The arch in 1979 [*Photo:* J. Vérité].

metres from the estimated final level, a beam plating was set on the two walls and the curve of the soffit was obtained with a cement capping. As we feared, the weight of the soffit produced subsidence of its upper part. But our construction was too mathematical and did not take into account differences of level (up to 5 cm) produced by setting difficulties when the arch was built. After the first mounting and a precise field-glass survey, the archstones were taken down and the capping corrected according to the previous data. Then the archstones were replaced on the soffit, adjusted and set according to the usual method.

Another building restored

This was the Julii mausoleum located near the Mustis arch. The analysis of stones found on the ground indicated that several of them belonged to that monument and that two courses could be restored. The building was not very high, and it seemed interesting to test the possibility of rebuilding it with a tripod as was done in Roman times. There was a crab on one of the legs of the tripod upon which a winch could be set. With the help of the leg, fixed in place with rope, the mausoleum was restored.

The tripod used at the Julii Mausoleum—two 'stones' made of gravel concrete (3:8) [*Photo:* J. Vérité].

The severe drawback of the system was the heavy weight of the tripod and the size of the base which hindered movements aimed at placing the top of the tripod in a vertical position against the final position of the stone.

By the completion of the operation, the workers had become experienced professionals. The number of the various courses (classification by alphabetical order) and the distribution of the stones by course (classification by colour and number) had become familiar to them.

It was difficult for them to read plans on a small scale (2 cm/m), and therefore drawings were made on a larger scale (5 cm/m) and the colours matching those of the classification were reproduced; by simply reading a number, the final position of each stone could be located. At the end of our stay in Tunisia, the arch was not entirely restored although the last course was already partially set. But a month later we returned to find that it had been completed.

RESTORATION SITES OF THE KARNAK TEMPLES (EGYPT)

Since the end of the last century, extensive restoration work has been done on the Karnak temples. Due to the large amount of remains and the dimensions of the stones restored, these operations have always been spectacular. Having worked with the Franco-Egyptian Centre for the Karnak Temples for several years, we believe that they hold out several lessons, some of which have been described below.

Eleven columns in the Hypostyle room of the Amon temple collapsed in 1899, no doubt because of the alteration of the water-table resulting from the construction of the first Aswan dam. At that time, one G. Legrain, in charge of the conservation of the temples, started restoration work immediately. The size of the blocks to be moved made the problem even more complex. Although the shafts are built with rollers or semi-rollers, the architraves are in one block and may weigh as much as 50 tonnes. The engineer Legrain had to remove a few of them to take down the rollers of the shafts. He chose to use the ancient Egyptian technique and build an earth ramp. Three hundred workers carrying baskets on their heads spent three months building a mound of earth fourteen metres high. Its edges were strengthened by dry stone walls (in the Hypostyle room) or left with a slope similar to the natural incline. The architraves were then lifted and 'packed' in a wood structure bound by metallic parts. The whole piece was set on wood cylinders which turned on a rolling surface made of large wooden beams placed on the ramp. The architraves were pulled by the workers towards ground level. The dismantling of the shaft rollers was done by removing the earth little by little and by dragging them down the ramp thus obtained. After consolidating the foundations, the columns were reset with a tripod but the architraves could not be remounted because of their size and weight.[1]

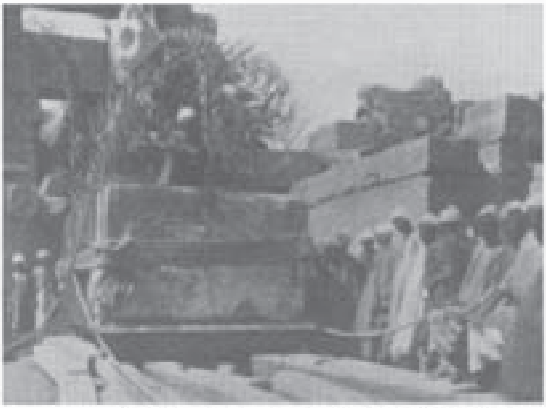
In the 1920s, Legrain worked on the dismantling of the third pylon of the Amon temple. He aimed at strengthening and restoring the pylon which forms one of the partition walls of the Hypostyle room and also at recovering the constituent stone blocks which had been taken from previous buildings (these blocks were used to restore two chapels, one of which is from the twelfth dynasty). The size of these stones was approximately one cubic metre. Dismantling was begun with an earth ramp. Legrain was not pleased with this system, for it was too slow and wasteful of human energy. He thought up the construction of a rolling gantry. Since the lateral facings of the pylon were in place, their upper course could be used to roll along a metallic beam. A mobile pulley-block made it possible to reach all the filling stones of the pylon, to extract them and convey them to the classification area.

The technology used on the Karnak temples sites for consolidation purposes was changed drastically by the use of wood scaffolding. Taking into account the size of the stones to be moved, planks in sections of 20 × 20 cm and 30 × 20 cm were chosen. A team of carpenters was formed and in the 1940s, under the direction of a certain Mr Chevrier, one of the severely cracked architraves of the axial columns in the Hypostyle room of the Amon temple was rebuilt with the help of a twenty-metre-high wood scaffolding able to support a weight of thirty tonnes. This consolidation work would not have been possible otherwise or without the use of concrete parts. A few years earlier, this architrave would have been taken down, and the restoration of the decorative masonry screen which is placed above it would not have been carried out. This is what today gives an extraordinary dimension to the Hypostyle room.

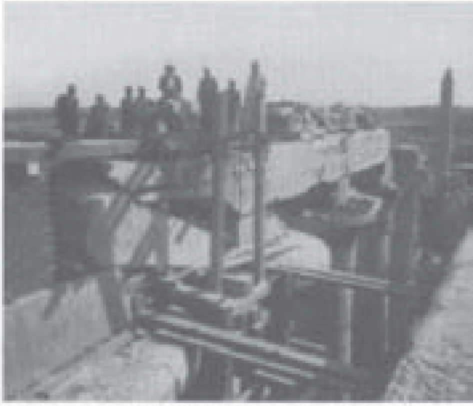
An interesting experiment conducted by Chevrier was the removal of obelisk fragments. During the restoration of the third pylon, he had to clear the courtyard located between the second and third pylons which was congested by numerous fragments of an obelisk broken after a fall. He wished to expose horizontally one of the largest fragments (eight metres long and weighing sixty tonnes approximately) at a height of one metre. He managed to do this by using four levels (large scaffolding beams each operated by thirty workers). The operation was done in various stages by successive wedgings. The experience is worth mentioning because it opens up new perspectives on ancient techniques of removing obelisks, and shows that large pieces can be moved with limited means.

In 1968, the Franco-Egyptian Centre for the Karnak Temples started the excavation of the axial zone of the third pylon of the Amon temple. A thirteen-tonne obelisk fragment had to be

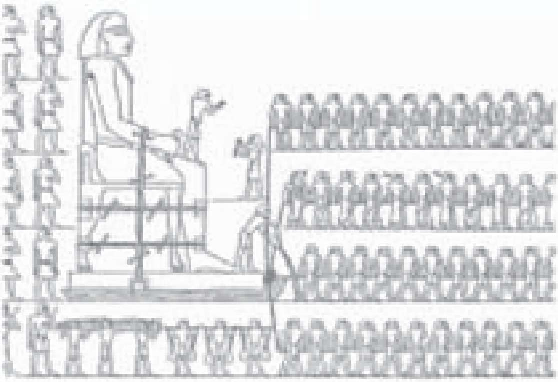
1. These operations are described by G. Legrain in *Karnak Temples,* Brussels, Fondation Reine Elizabeth, 1928.



Architrave being dismantled [*Photo:* CNRS].



Upper portion of scaffolding, twenty metres high [*Photo:* CNRS].



Statues being moved in ancient Egypt (From: P.E. Newberry, *Les Pyramides d'Egypte*).

Sledge on rollers [*Photo:* CNRS/A. Bellod].

removed. The method selected by the chief of the worksite, Mr Laronde, is interesting because it combines techniques both very ancient and totally modern. The operation was conducted in the following way: the large block was placed on a wooden sledge moved by pulling. The first stage was to move the stone block from the corner where it had stood. It was first lifted with hydraulic jacks. Then two skids were placed on a rolling plane constructed from thick timbers on which guiding corner-irons were set. This was placed by wedging at a level slightly higher than the level of the sledge already laid on wooden rollers (the same as those used by Legrain in 1900). The lateral dragging was then done with a winch operated by three workers. It was made easier by pouring oil between the skids and the rolling surface. When the sledge was reached, the dragging stopped. The block was lifted again with hydraulic jacks after removing the rolling plane placed on the sledge. It was similar to the block which appears on the partition walls of the tomb of Djehoutihotep in El Berchech with the exception that the timbers were joined together with bolts. To pull the twelfth-dynasty sledge, 172 men were needed because of the weight loaded (estimated at 60 tonnes) but also because it was sliding directly on previously moistened soil. In Karnak the use of rollers made the task easier. The sledge was pulled by a light tractor pushed in starting by twenty men (the rubber tyres tended to slip on the stone slabs). The operation would have been very rapid had it not been for some difficulties when the loaded sledge had to be turned. Experience showed that a single roller had to be used to swivel on the inside of the curve: besides, it appeared necessary to place the rollers at a certain distance from one another on the outside to prevent them from touching each other and impeding movement.

SOME GENERAL CONSIDERATIONS ON APPROPRIATE TECHNOLOGIES AND THE RESTORATION OF HISTORIC MONUMENTS

The above-mentioned examples are a partial illustration of the use of 'appropriate technologies'. Applied to rural development, such technologies may be defined in the following terms.

1. They use a great deal of manpower and help to create a large number of jobs.
2. They are not very costly and can be amortized on a long-term basis, therefore can easily be associated with the limited financial resources of the human group concerned.
3. They are easy to conceive, to adjust and to use, that is to say in keeping with the technical knowledge of the users.
4. They use local materials rather than materials imported from foreign countries or distant places.
5. They favour small-scale decentralization rather than concentration in large units.
6. They tend to produce goods and

services aimed at the satisfaction of primary human needs rather than the production of luxury goods for a privileged minority.

7. They use various energy resources locally available and save a maximum of energy.
8. They do not have a strong influence on the enrionment, that is to say they make it possible to strike, on a long-term basis, an essential agro-biological balance and lead to a rational use of the environment.
9. They take into account limiting factors such as the depletion of some rare resources.
10. They are under the control of the people concerned and help them to take part truly in the various stages of technological development.
11. They consider the traditional elements as a fundamental base which is valued by developing local creativity; by the use of these traditional elements, they remain in harmony with the cultural environment of the group.
12. They strengthen the autonomy and independence of the human group concerned at the macro-economic level (national independence) and at the micro-economic level (relative self-sufficiency of the village and the family.[1]

As against the above, the monument conservation-sector has an ambiguous status in developing countries. It is often said that 'the preservation of monuments and of some archaeological or historical sites is connected to a large extent with foreign visitors since it is to please them and to satisfy their curiosity that the authorities have made the efforts required for the protection of those sites and monuments'. Is not tourism in many cases the only justification and lever for obtaining the necessary financing for monuments? It is thanks to tourism that many conservation services have been able to carry out spectacular operations with or without advanced or 'dominant' technologies. In general, however, the monuments sector in developing countries is relatively marginal and very seldom receives any financial priority. It is not a production sector like agriculture, and its budgets are the first to be reduced if money is short. The monuments services are generally linked to one or various central administrations and they lack experts (art historians, architects, specialized craftsmen) to carry out their task. The tendency to use foreign experts either makes them more dependent on imported technologies or prevents any effective achievement. The limited resources allocated—apart from the spectacular achievements—make it difficult for this sector to increase its limited role in the 'modern' sector of the economy. Thus it is very difficult to find the parts required to maintain machinery or to hire qualified workers (trained, specialized workers tend to find employment in the private sector where salaries are higher). Gener-

1. J. M. Collombon, *Appropriate Technologies Applied to an Alternative Strategy of Rural Development.* (Mimeo.)

ally speaking, the monuments sector is therefore unable to use advanced technologies. Its links with the rural sector should be made even stronger because it can create jobs for unspecialized workers.

The preceding analysis suggests that appropriate technologies in the conservation of monuments cannot promote development and local participation as such. Their essential usefulness is to make the best of a poverty situation and this is why, among the characteristics listed above, the following appear to be the most important:

1. They are labour-intensive.
2. They are not costly.
3. They are easy to conceive, to implement and to use.
4. They favour the use of local materials.
5. They use local energy resources.
6. The traditional elements are considered as basic.

The presence within the monuments sector and its environment of modern technologies makes it essential to add the following:

7. They permit a reduction in sheer physical effort on the part of the workers and improve their working conditions. For this purpose, modern techniques would be used to the extent possible, either directly or in a way that, through adaptations, makes them locally accessible.

DISCUSSION OF THE EXAMPLES CITED

The restoration of the Mustis Arch is a good example of a mix of modern technologies and 'appropriate' solutions, even if it is often difficult to distinguish clearly between the two. However, too much concrete was used. The piers could have been filled in with masonry of local stone, in order to save the expense of bringing material from far away. Nevertheless, it is worth stressing the usefulness of setting concrete with a tractor because it saves a great deal of physical effort. The labourers in fact acquired the technical know-how needed to make concrete, for after having seen the moulding work on the site they used concrete leftovers to precast lintels and jambs for their own houses. Thanks, on the other hand, to the traditional elements used, the wedging of stones was made easier because it corresponded exactly to the building style of their dwellings. The scaffolding now seems of arguable value. Great lengths of pipe could have been saved by placing the mobile system at a higher level, moving it with ropes and a pulley-block. The ancient tripod system could have been used. We were insufficiently sure of the technical skill of the workers, and dared not use the tripod system for the rebuilding of the arch. But the resetting of the mausoleum of Julii showed that the technique remained valid and could be easily used by the workers. A few years later in Sbeitla, the tripod system was used again with an electricity pole to build a reception centre on the site. The same principle was used yet again, to restore the west arch of Mustis (although the surviving fragment reached up to the level of the abutment only).

The Karnak temple examples show what can be done by labourers with only few technical means at their disposal. They demonstrated above all that appropriate technologies, making the best use of modern technology, are labour-saving. A small investment did away with the long drudgery of building earthworks. The construction of a gantry to dismantle the third pylon of the simple use of wood scaffolding completely modified the working plan on the site and avoided the need to remove large quantities of earth. Using an imaginative traction system to remove the obelisk sledge, the work was made more humane, whereas in ancient times it was done only by slaves. Is the use of modern equipment in contradiction to the concept of appropriate technology, which stresses the need to use a maximum of manpower? The basketful of earth used to build a dam which will benefit its builders cannot be equated with a similar basketful used to restore a monument. The ultimate usefulness of technology is that it helps bring about a higher level of social welfare. The restoration of monuments cannot fulfil this role unless it makes it a principle to create jobs and save as much of the labourers' energy as possible, through making the most judicious use of modern technology and equipment. Those in charge of conservation in developing countries cannot afford to neglect machines which are lying unused, for example, or which are available on a part-time basis. All machinery not in working order should be repaired, saved from its non-functionality, and thereby made 'appropriate'.

'Appropriate' Indian technology for the conservation of museum collections

O.P. Agrawal[1]

INTRODUCTION

When discussing the use of appropriate technology in the conservation of museum collections, one has first of all to understand the significance of the terms employed. The International Institute of Conservation, London, has definded conservation as 'any action taken to determine the nature or properties of materials used in any kind of cultural holdings or in their housing, handling or treatment, any action to understand and control the causes of deterioration and any action taken to better the condition of such holdings'. Conservation of museum objects, therefore, will mean any action which is taken to prevent, delay or stop deterioration and also any action taken to treat objects with the intention of correcting any alterations that have come about. Obviously, the term conservation is wide enough to embrace both the maintenance of the object in a sound physical and chemical condition as well as freeing it from any harmful inclusions.

The concept of 'appropriate technology' is the result of new thinking concerning modern technology and its effect on society. In the developing countries the question of choice of technology is being discussed at various levels and from several points of view. In fact, many of the developing countries are now faced with a peculiar dilemma. The use of sophisticated imported technology has not given the results which were desired and sought after. This is because research efforts have not been directed towards the development of technologies which fit the needs and possibilities of these countries.

In museums, many modern Western techniques of storage, air-conditioning and chemical treatment of objects are very costly. There are, however, various traditional techniques which could take care of many of these needs yet which are not pressed into service either because modern techniques are always considered to be superior or because the traditional techniques have been forgotten and are not known to curators. When modern Western technology is adopted for museums in developing countries it is forgotten that in many cases it requires both a very high capital expenditure and easy availability of materials. Both these conditions are often difficult to meet in developing

1. The author is grateful to his colleague, Mr Shree Muni Singh, for his suggestions and help in the collection of materials, and to Mr H. S. Bora, who took the photographs.

countries, where technical breakdowns, energy shortages, lack of imported chemicals, equipment, and so on, are rather frequent. Most museums are themselves short of financial resources and the technical know-how is not available. For this reason the techniques which have been used successfully for centuries in traditional households for storage and maintenance of materials can be extremely beneficial. By suitably adapting these technologies, the problems of advanced technology can be avoided, and the non-availability of resources within the country can also be countered to a great extent.

There are several traditional Indian techniques used for the preservation of objects which can be applied even today. Needless to say, a great deal of research and survey still needs to be done in the field before we can be certain of the efficacy of many of these methods. The notes on the following pages may seem slightly disjointed in as much as they represent an attempt has been made to collect together information from various sources as well as to include the personal experience of the author. Described below are some materials commonly used as insecticides. Also mentioned are techniques to reduce the effects of tropical climate and to store materials.

INSECT REPELLENTS/INSECTICIDES

Normally paradichlorobenzene or some other similar fumigant is used to protect books, manuscripts, textiles, etc. against insects. Apart from the cost, a very serious drawback in the use of these insecticides is their very offensive odour. Unless the cupboards are airtight the fumes which are emitted are obnoxious and if inhaled regularly, may cause respiratory trouble. These chemical products are very often not easily available and are also costly for regular use in museums. There is, therefore, a great need for research into an alternative natural products.

In India, as well as in some other countries, several natural products have been used for protecting household goods, particularly books, religious manuscripts, textiles, wooden furniture, etc., from the attack of insects. Some efficacious and others less so. The most commonly used natural insects repellent are: leaves of *neem* (margosa) tree, camphor, ghora-buch and so on. We do not at present know enough about them to be able to ascertain their real value. In fact, several problems need first to be resolved, in particular: (a) identification of the insects against which each of these insecticides/repellents is effective; (b) duration of effectiveness; (c) optimum quantitites to be used; (d) whether mixtures will be more effective. A special project is required to study these and other related problems. The account given below is based on personal inquiries and observations.

Neem leaves

One of the most common and readily available natural products used as an insecticide is the *neem* leaf. In view of their effectiveness, *neem* leaves certainly deserve our attention. In Indian villages and small towns, people still use dried *neem* leaves to protect textiles, manuscripts and books. The *neem* tree (*Azadirachta indica*) is a native of India, but has today spread throughout the tropics, including Africa. There is a peculiar bitter taste in all its parts. For use as an insecticide, the leaves are dried in the shade, never in direct sunlight, and kept together with the materials to be preserved. In several cases known to the author where these leaves were in regular use, the materials had indeed remained free of insects, although normally one would have expected to find hordes of them.

A former superintendent of the museums branch of the Archaeological Survey of India, the late Dr V. S. Agarwal, in the early 1950s described to the author a very interesting episode which illustrates the efficacy of *neem* leaves against insects. Dr Agarwal had gone to Jaipur to examine the personal collections of the Maharaja of Jaipur with the intention of acquiring if possible some objects for the National Museum which had just been established at New Delhi. He was told by the palace authorities that there was a woollen Mughal carpet, of the finest quality, measuring about 9 × 4.5 m, some 150 years old at that time, stored in the *Tosha Khana*.[1]

When Dr Agarwal came to know of the carpet, he wanted to have a look at it, but knowing that it had been kept in the Tosha Khana for so long, unattended and possibly without ever having being taken out, he was almost certain that what he would see would be a moth-eaten bundle of rags. To his surprise what came out was a huge crate apparently full of *neem* leaves. The leaves were removed and buried inside them was the woollen carpet. When it was unrolled, the great scholar was astonished to see that nowhere was there any insect damage. What is more, the carpet was in a totally flexible condition literally as good as new!

The *neem* (margosa) tree is found all over India and Burma. It is a large tree and grows wild in the forests of South India. The tree can be seen everywhere on the roadside and inside the compounds of houses.

The girth of the trunk can measure as much as two to three metres. Its bark is moderately thick. Its seed gives an oil (margosa oil) which is acrid and bitter in taste, and has been found to contain sulphur. The bitter principle of the oil has been extracted and identified as nimbidin. It is highly prized for its medicinal properties. Almost all parts of the tree are useful to man in some form or another. As mentioned earlier, the leaves are used for protecting books, papers, clothes, etc., against insects. Investigations show that an allyl

1. The store room where precious belongings of the palace are stored.

compound is present in the leaves. It has also been found that, when burnt, the dried leaves give off an odour that is fatal to insects.

For use as an insecticide, the green leaves are dried in the shade and kept in boxes and cupboards under and near to the objects. Direct sunlight is said to destroy the insecticidal properties.

Besides their effect on insects, *neem* leaves may also act as a buffer for maintaining normal humid conditions inside storage cupboards. It is known that the inclusion of organic woody substances inside cupboards helps to maintain a balanced relative humidity. When the relative humidity is high, they absorb part of the moisture and give it off when conditions are dry.

Camphor

Camphor (*Cinnamomum*) is another natural product commonly used in India to protect valuable documents and papers from insects. Packed in small cloth pieces or bags, it is kept inside the cupboards in which these materials are stored. The camphor tree is a native of China and Japan, and at some stage was introduced into India and many other countries. It is now cultivated as a source of camphor. There are many varieties of the *Cinnamomum camphora* tree, of which a few provide camphor while others give only an aromatic oil. Camphor is formed in the oil cells distributed throughout all parts of the tree. The formation of these cells starts early in its growth. A clear yellow oil is formed in the cells, which is ultimately deposited as camphor.

The two main varieties of camphor tree are the above-mentioned *Cynnamomum camphora* and *Dryodalanops camphora*. Chips of the wood of the former are boiled in water and the vapours are cooled, yielding a white crystalline substance, i.e. camphor. In the case of *Dryodalanops camphora*, the camphor crystals are found naturally in the stems of the trees.

Camphor finds its main uses as a medicine and for worship in Hindu households.

Tobacco

Villagers in India often use tobacco leaves to protect their woollen clothes against insects. The dry tobacco leaves are packed in pieces of cloth or cloth bags and kept inside boxes in which textiles are stored, pervading the boxes with their aroma. Sometimes they are spread on the bottom of storage boxes. It is possible that the tobacco leaf owes its insecticidal properties to the presence of nicotine, which is highly poisonous. It also contains several substances of the phenol, polyphenol and tannin variety.

Black cumin

It is reported that black cumin seeds (*Nigella sativa*) were commonly used in certain Indian houses as an insect repellent. The seeds, either alone or mixed with powdered camphor, were sprinkled between the folds of textiles, particularly woollens, to prevent attack by insects. These seeds are also used for several medicinal purposes. They contain a volatile oil, which probably accounts for their insect-repellent property.

Nigella sativa is a small herb about forty-five centimetres high, which is cultivated in several northern states of India. Its main use is in cooking, for instance in the preparation of curries, and in medicines. The seeds contain volatile and fatty oils, tannin, resins, proteins, etc., as well as a bitter principle named nigellin.

Vitex negundo

Vitex negundo, called *nirgandi* in Hindi, is a deciduous shrub commonly found throughout India. After being dried in the sun, the leaves of this shrub are inserted between bundles of palm-leaf manuscripts, which is alleged to keep the insects away. Being non-poisonous to animals, it is also used to keep fodder and grain free of insects. The bark of the tree also acts as an insect repellent.

Turmeric

In several parts of India, it is a common practice to rub a paste made from turmeric onto palm-leaves. This imparts a slightly yellow colour to the palm-leaf. Turmeric, which is normally used in Indian households as a spice in curry, also has disinfecting properties. Palm-leaves treated with turmeric solution acquire an insect-repellent property. Turmeric is also used as a medicine. It is prepared from the roots of the shrub *Curcuma longa*. The roots have to be specially treated before they are fit for use. After being dug up, they are boiled on a slow fire in closed earthenware pots and dried in the sun.

Sweetflag

The rhizome of *Acorous calamus* is said to have insecticidal properties, and is used as such with textiles and documents in many Indian households. It is a semi-aquatic perennial herb with a creeping, many-branched aromatic rhizome. The rhizome itself is cylindrical or slightly compressed. It is light brown in appearance, the inside being white and spongy.

Sweetflag is found wild and sometimes cultivated throughout the Indian subcontinent and in Sri Lanka, growing particularly at high altitudes of 1,000 to 2,000 metres. A damp, marshy climate is conducive to its growth. It is commonly used by certain tribes living in the north-eastern region of India, for example in Assam and Nagaland, for protecting their clothes as well as for medicinal purposes.

When used as an insecticide, the powder made from the roots is packed inside pieces of cloth or in small sachets and kept in the closed cupboards in which the manuscripts are stored. It has been found particularly useful against moths, flies, etc.

The dry rhizomes have a mellow odour, and contain 1.5 to 3.5 per cent of a yellow aromatic volatile oil. The sweetflag probably owes its insecticidal properties to the presence of this volatile oil.

The author observed its use in the Oriental Research Institute, University of Baroda, for the preservation of palm-leaf manuscripts and paintings. In some libraries it is used in a mixture with other herbs.

Sandalwood

Sandalwood (*Santalum album*) provides one of the oldest perfumes used in India. Sandalwood paste is used for purposes of worship in households and in temples. On festive occasions, it is applied to the foreheads of guests. Sandalwood dust is believed to have insect-repellent properties. In many traditional households, sandalwood dust packed in cloth is kept inside cupboards or boxes in which textiles, particularly woollens, are stored.

The sandalwood tree is a small-to-medium-sized semi-parasitic evergreen, commonly found in dry regions of southern India, especially in Karnataka and Tamilnadu. Its bark is reddish, dark grey or black. The wood is white or slightly creamy in colour, having a very mild scent. The heartwood contains an essential oil which is extracted by distillation. Both the sandalwood itself and the oil have been employed for medicinal purposes. Sandalwood powder is also used as an incense.

Peacock feathers

In India, keeping peacock feathers inside books and manuscripts is commonly believed to have very beneficial effects. One feather is inserted after every ten or fifteen leaves. It has been observed, for reasons yet unknown, that paper materials that have peacock feathers placed between their leaves do not ordinarily attract bookworms. Students are commonly encouraged by their parents to keep these feathers inside their books.

Snake slough

Insecticidal properties are also attributed to the slough of snakes. A piece of this slough kept between the leaves of books has commonly been observed to keep them free of bookworm.

Orpiment and realgar

Orpiment, which is slightly yellowish in colour, and realgar, which is orange-red, were commonly used as pigments and for dyeing textiles. Both these minerals were sometimes used to colour certain kinds of paper. It was observed that this treatment protected the paper against insects. Since orpiment and realgar are arsenic sulphides, this property is understandable.

The author has examined some eighteenth-century paper manuscripts at the Sarasvati Mahal Library in Tanjore. In some of these, alternate pages were yellow, having been treated with orpiment.

The manuscripts were free of insects.

It has been observed that termites do not breed in areas where the banana plant is grown. When the plant is grown all around a building, it is claimed that, for some mysterious reason, the building remains free of termites. Nor are the roots of the banana plants themselves attacked by termites. It is a common practice to grow banana plants inside the house. The author was informed by R. C. Sharma, the Director of the State Museum in Lucknow, that, when he was stationed at Mathura, there was once a threat of termite infestation in one of the rooms of the museum building. He was advised to grow banana plants near the room, which he did, and found that the termites were indeed eradicated from the area.

In some places, a mixture of several herbs is used as an insecticide. At the Sarasvati Mahal Library at Thanjavur, the author observed the use of a mixture of the following spices: 1 kg of black cumin seed; 1 kg of white sweetflag; 250 grams of cloves; 250 grams of pepper; 250 grams of cinnamon bark; and 50 grams of camphor. All the above materials are compounded to a fine powder, which is wrapped in small pieces of cloth and kept in different places in the cupboard. It is claimed that the insects do not then attack the documents.

In several institutions, the different ingredients, in particular black cumin seed, white sweetflag and camphor, are used singly. The use of a mixture is probably to be preferred as each of the ingredients may be effective against only one species of insect. A mixture may, therefore, give immunity against a number of different species.

Mrs Pupul Jayakar, adviser to the Government of India, All-India Handicrafts Board, described to the author a special technique of storing woollen shawls she had seen used in Kashmir. In the Srinagar Tosha Khana, the shawls are folded and neatly packed one over the other into a bundle. This bundle is placed between two wooden boards, which are then tightly bound with a strong rope. In this manner a good deal of pressure is exerted upon the two boards. When the bundles were opened in her presence, she found that the colours both of the shawls and their embroideries were as fresh as ever. Moreover, there were no insects in the material.

The reason for the shawls' safe-keeping could be the absence of moisture and light as well as the squeezing out of air from the tightly bound bundle.

CLIMATE CONTROL

The importance of climate control for the preservation of museum objects is widely recognized. Too dry or too wet conditions can be extremely harmful to art objects, particularly those of an organic nature. Air-conditioning of museum buildings is often recommended. However, air-conditioning is a costly proposition. Also, the running cost of the plant is almost always beyond the financial resources of most museums.

A *khas* screen. *Khas* curtains are hung on the windows and doors in the house and water is sprinkled on them to humidify the air inside the room [*Photo:* H. S. Bora].

The uncertainty of constant electric supply is another factor which cannot be overlooked. In the case of the failure of air-conditioning plant possibly more harm could come to museum objects than without air-conditioning.

In view of the difficulties involved in the use of air-conditioning, alternative means of climate control will have to be adopted. In northern India, the climate is very dry during the summer months, particularly from April to June. In some areas, relative humidity drops to 10 or 15 per cent. To meet this situation the device traditionally used in Indian houses is the use of curtains or screens made of *khas*, the roots of a perennial grass.

The screens of *khas* are hung like curtains on the windows and doors in the houses. Water is sprinkled on them and the air is thereby humidified while at the same time, a fragrance is imparted to the area. During the summer, these curtains are in use in many houses.

Khas is a small genus of the perennial grass, *Vetiveria bory* (*Gramineae*), found in the tropics. Two species are found in India of which *Vetiveria zizanioides*, commonly known as vetiver is more common. This species is the source of the well-known oil of vetiver which is used in medicine and in perfume. Vetiver was known in India from very early times. It has always been highly prized as a perfume. *Khas* grows wild in almost all parts of India; in some parts it is also cultivated. However, cultivation meets only a very small percentage of the total requirement of *khas* in the country.

It is a densely growing grass with sponge-like roots. The leaves are narrow and erect. The roots are used for making screens as well as for the extraction of oil. The colour of the roots varies from light yellow or yellowish to reddish yellow. The roots are distilled to obtain the commercial vetiver oil. It is a light reddish brown, sometimes greenish, viscous liquid having a characteristic and persistent aroma with pleasant woody character. The custom of making screens from the roots goes back to ancient times. The screens are placed on windows and doors and the air is cooled as it passes through. The property of *khas* is that it can retain water for a long period. It is also believed that it possesses antifungal and anti-bacterial properties, but this will have to be determined through scientific research and experimentation.

Besides being used for the distillation

of oil and making screens, the dried roots also serve to scent linen and cloth.

Museums which cannot afford air-conditioning can possibly use these *khas* screens on their doors and windows. In the National Museum in New Delhi, *khas* screens are in fact fixed on the main entrance doors, as well as on some windows every summer. This has a very salutary effect on the micro-climate of the building. A difficulty arises because of the flowing water which is sprinkled on the screens. However, if a channel is fitted at the bottom of these screens to carry away the flowing water, the problem can be solved to a great extent. On the top of the screen a tube with small holes can be fitted through which water will flow and trickle onto the screens to keep them continuously wet.

ADHESIVES

The need for suitable adhesives is always felt in the conservation laboratory. In the treatment of Indian miniatures, a frequent requirement is the pasting of a new sheet backing onto the original painting. This pasting has to be done in such a manner that the whole assembly of painting and new sheet remains flexible. Similarly, paintings on cloth are sometimes backed with tissue paper. This mounting should also remain flexible.

The paste normally employed for this purpose is prepared with *maida* (fine wheat-flour). Its comptability with the paper materials makes *maida* paste a very good adhesive. However, a commonly observed drawback is the imparting of a slight stiffness to the painting assembly. The search for traditional adhesives has yielded information concerning two types of pastes used by traditional artists. These are prepared from tamarind seeds and whole wheat.

Tamarind seeds

The seed of the tamarind fruit is used for preparing a type of gum. The outer shell of the seed is reddish-brown in colour and its pith is white. To prepare the paste, the seeds are first thoroughly washed in water to free them from the attached pulp. The bad and hollow seeds, which float on the surface of the water, are discarded. The good seeds are then allowed to soak for two or three days, until the red skin peels off. The white pith is then boiled in water, yielding a paste-like substance which is then strained through a fine cloth. The resulting clear liquid is stored and can be used as a gum for pasting papers together. It was commonly used as a binding medium for paint, particularly in southern India.

In addition to the pasting of paper, tamarind-seed paste can be used to restore lost strength to the binding medium. If the paint on a miniature painting is flaking off its backing, a protective coating has to be applied to the surface. This protective coating is normally prepared by dissolving a resin such as polyvinyl acetate or polymethyl methacryl-

Palm-leaf manuscripts were always kept between two strong wooden boards around which a cord was strongly tied [*Photo:* H. S. Bora].

ate in a suitable organic solvent. The author has observed traditional artists using a very dilute solution of tamarind-seed gum for the same purpose.

The tamarind tree (*Tamarindus indica*; in Hindi it is called *imly, amli* or *ambli*) is a very common and important tree in India. The tamarind fruit is used in the preparation of various Indian foods. It possesses a sweetish acidic brown pulp. The seed kernel contains a polysaccharide which is known to have excellent sizing properties. It is extensively used as a sizing material in the cotton industry.

Analysis of the tamarind kernel shows that it contains in addition to polysaccharide proteins, fibre, fat, certain inorganic salts, sugar and tannin. Its sizing property is undoubtedly due to the presence of the polysaccharide, known as jellose.

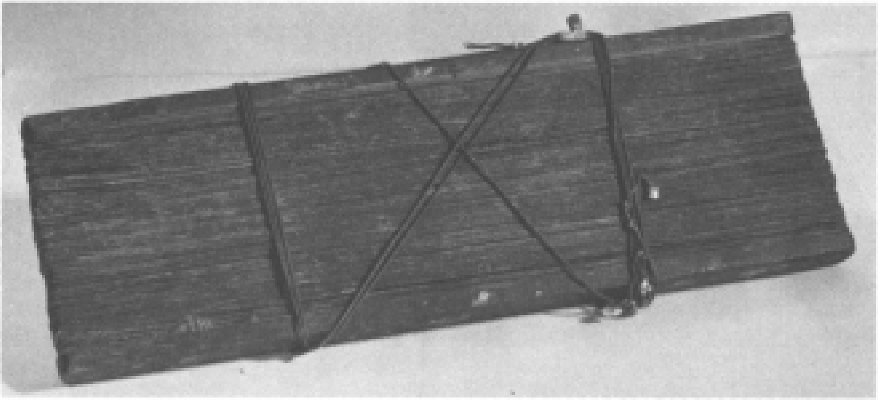
It is reported that, when boiled in water containing boric acid, tamarind-kernel powder makes a very good paper adhesive. Phenol is used as a preservative.

A paste can also be prepared from the juice of whole grains of wheat. To prepare it, wheat grains are soaked in water for twenty-four hours until they become soft and pulpy. They are then squeezed between the fingers to yield a white juice. This is strained through a piece of cloth and the liquid collected in a metal receptacle. It is then boiled over a low fire until it turns into a paste. Water is added to the paste and the mixture stirred well. The paste is strained through a fine muslin cloth and mixed with an insecticide before use. Thus prepared, the paste has the advantage of remaining flexible for a long period. In fact, what the soaking, pounding and straining does is to extract the starch. By this process, the hard outer proteinous shell of the wheat is left behind. This may account for its flexible nature. In Japan, proteinless starch is used for the mounting of scrolls.

STORAGE

For the storage of manuscripts and books there are several traditional practices which will be of interest to conservators even today. Palm-leaf manuscripts, for example, were always kept between two strong wooden boards around which a cord was strongly tied. This practice helped to keep the palm-leaf flat and prevent it from curling. To a certain extent this also helped in retaining humidity. For the preparation of these boards, the wood of the margosa (*neem*) tree or *Michelia champaca* was preferred. The wood of both these trees is known to be insect-proof.

Books and manuscripts whether on palm-leaf or on paper were invariably wrapped tightly in a square cotton cloth. This practice helped to keep dust from reaching the books. Insects also had less chance of getting inside. Furthermore, the colour of the cloth was almost always red. Why red was chosen is difficult to say, although it has been mentioned that red cloth was supposed to be auspicious. However, it is possible



that wrapping a manuscript in red cloth prolonged its life by excluding ultra-violet and near ultraviolet rays of light. Here again, however, the unconscious scientific wisdom of this practice is yet to be proved scientifically.

It is also possible that wrapping of manuscripts in cotton cloth helped in the retention of humidity at a desirable level. It is often recommended that cup-boards and show-cases containing organic material like paper and palm-leaves should also contain plenty of hygroscopic materials like silica gel, sawdust or cotton. It is obvious that a case of cotton cloth all around the manuscript would serve that purpose admirably.

DETERGENTS

There were several natural products used in India as soap substitutes. Perhaps the most important of these materials was derived from the species of tree, *Sapindus*. The fruits of the *Sapindus* were very widely used for washing textiles, particularly before printing and dyeing. It was found that certain special results in dyeing could be obtained by using these nuts for washing the fabric before they were dyed and that a similar result could not be achieved by using soap. It is possible that some of the natural detergents produce a type of chemical reaction with the textile not achieved by soap.

Till very recently soap-nuts (*ritha* in Hindi) were extensively used in India for washing woollen as well as silk clothes. In fact, they were preferred to soap. The nut is of light brown colour with a black seed. The outer shell is soaked in water till it becomes pulpy. On mixing with water the pulp gives a lather which has detergent properties. It has been observed that even most delicate fabrics, particularly dyed and fragile ones, may be washed with *ritha* without affecting the colour.

As mentioned above, there are two distinct species of soap-nut tree: *Sapindus mukorossi* and *Sapindus trifoliatus*. The *Sapindus mukorossi* is found mostly in northern India while the latter in central and southern India. The tree is found wild but is also cultivated. The nuts contain the principle termed saponin. The nut skin contains about 10–12 per cent saponin.

The soap-nut is also used for washing and restoring the brightness to silver and gold ornaments which have become tarnished. The ornaments and other objects are dipped in the solution and brushed lightly with a tooth brush.

The shine of the silver is thereby restored.

An examination in our laboratory has shown that *ritha* solution in water has non-ionic or slightly acidic properties. For all conservation work non-ionic detergent is preferred. Weakly acidic solutions can be safely used for woollens and silks. In addition, it is also found that the flexibility of silk and wool is not impaired by the use of *ritha*. Further experimentation may suggest other possible uses of this traditional detergent for conservation work.

Another detergent much in use till recent times was *Acacia concina*. The pods of this bush were extensively used as a detergent, particularly for washing the hair, and for woollen clothes. It is popularly believed that the solution gives hair a special shine, and has the additional property of causing it to grow thickly. The dry fruits of *Acacia concina* contain about 5 per cent saponin.

Acacia concina is a common thorny bush, found throughout the forests of India, particularly in the south. It is also widely distributed in Burma. Each pod contains some six to ten seeds. When dry, they are brown in colour and wrinkled. The bark is used for dyeing and tanning. However, for the conservator it is its detergent property that is of most interest. The common defect of most soaps is their tendency to remove oil and lanolin from wool. Natural products may prove better in this respect.

Metal cleaning

Tamarind pulp is commonly used in Indian households for the cleaning of metal utensils. Thanks to the several acids it contains, the cleaning is quick. Tarnish and green encrustations are rapidly removed by rubbing the metal object with wet pulp. Whether it has any effect on 'bronze disease' is difficult to say. However it contains tartaric acid, both free and combined. Of particular interest to the conservator should be the presence of tartaric acid and tartarates. A solution commonly used for the eradication of bronze disease is sodium potassium tartarate. As far as tamarind pulp is concerned, the possible role of the potassium tartarate contained in it is a factor that requires further study. Almost half the tartaric acid in the tamarind fruit pulp exists in the combined form, mostly as potassium bitartarate. A small amount is also present as calcium tartarate also. The fruit also contains about 2 per cent of other constituents, mainly organic acids, such as maleic acid, oxalic acid, citric acid, etc.

Textile repairing

In the conservation of textiles, the application of a new backing material is often required. Frequently, there are tiny holes in the textiles that have to be filled in using patches of another cloth in such a way that they are not obtrusive. Also, the threads of embroideries or brocades come loose and have to be fixed back onto the textile support.

Stitching, darning and sewing with thread are still considered most appropriate for this purpose. Pasting gives a certain degree of stiffness to the textile–backing assembly. For all this work, a high degree of craftsmanship is needed. In India, there are still traditional craftsmen whose ancestral profession is darning or weaving of textiles by means of hand-looms. The manual dexterity of these craftsmen is quite matchless. It is possible to use their knowledge for the restoration of textiles in such a manner that the repair work is almost invisible unless viewed at close quarters.

Treatment of palm-leaves

Before paper was known, several other materials such as parchment, wooden panels and palm-leaves were used for writing and painting. Palm-leaf was the most common medium used in South and South-East Asian countries. The two main varieties of palm-leaf used were the palmyara palm and the talipot palm. Writing on palm-leaf was done with a pointed stylus, which engraved the letters or illustrations in the leaf. Surface writing with pen and ink, and painting with brush and paint, were also prevalent.

Whatever the species of palm-leaf or the method of writing and painting used, a common failing was loss of flexibility: with the passage of time, the leaves become brittle. Being a natural product, palm-leaf is also vulnerable to insect attack.

Certain traditional techniques for the preservation of palm-leaf manuscripts should be of interest to conservators. In India, many temples, and research institutions apply lemon-grass oil to palm-leaves. There are several species of grasses found in the tropics which yield lemon-grass oil. Indian lemon-grass oil is obtained from *Cymbopogon flexuosus*. West Indian lemon-grass oil is obtained from *Cymbopogon citratous*. *Cymbopogon flexuosos*, the source of Indian lemon-grass oil, is found mainly in southern state of Kerala. *Cymbopogon citratous* is cultivated in the western region of India, Sri Lanka, Burma, Indonesia and parts of South America. Lemon-grass oil has a pleasant odour. In some places, citronella oil is also applied to palm-leaves; this is obtained from another species of grass, namely, *Cymbopogon nardus*, known as citronella grass. It is cultivated mainly in Sri Lanka. Lemon-grass or citronella oil is applied to the palm-leaf either with a brush or cotton. The oil is allowed to penetrate into the leaf for about ten minutes, after which the excess oil is wiped off. It is believed that these oils keep the leaves flexible and ward off insects.

In Sri Lanka, two types of oil are applied to the palm-leaf, namely, *du du tel* and *dummela tel*. *Du du tel* is prepared by pressing the fruits of the balloon vine heart-seed, *Cardiospermum halicacabum*. *Dummela tel*, which is deep brown in colour, is obtained by the distillation of a fossil resin found in certain localities of Sri Lanka. It is reported that the application of *dummela* oil to the palm-leaf keeps it flexible. Incidentally, *dummela* oil was also used for the preservation of boats.

CONCLUSION

Mentioned in the foregoing pages are only a few examples of traditional technology which can be used appropriately to meet the demands of modern conservation. There were many techniques, developed as a result of keen observation, that were once in common use but are now forgotten. In most cases, no reason could be advanced for the use of certain types of materials for storage purposes or as insecticides, etc. What is needed today is an intensive survey of such materials, in order that these practices, which are now disappearing fast as a result of the growth of industries and the adoption of modern chemicals and dyes, do not become completely lost. If timely action is not taken, the knowledge they represent will disappear totally. There are still some craftsmen alive in India who are using them, but competition with modernization is proving too hard. For this reason, urgent action is required to retrieve and store this information.

The restoration of mud-brick structures in historical monuments of the Andean region of Peru

Roberto Samánez Argumedo

THE GEOGRAPHICAL SETTING

The Republic of Peru lies in the central part of the Andean cordillera and is characterized by a great variety of ecological regions; to changes in elevation correspond differences in terrain, climate and type of vegetation. The country consists of three very different regions.

First, the coastal belt to the west of the Andes, which extends over nearly 6,000 kilometres, adjacent to a marine upwelling of the deep waters of the Pacific Ocean which gives rise to abundant marine life as well as to overcast skies and no rainfall, a situation completely untypical of the tropical region.

Second, the Andean mountain range which runs along the coast is crossed by a large number of rivers which flow down to the coastal desert belt, forming valleys with highly productive farm lands cultivated over the centuries. Longitudinally, the cordillera is broken into discontinuous stretches. To the west it is bounded by the headwaters of the coastal rivers and to the east by the rivers of the Atlantic basin, which descend abruptly, forming gorges, canyons and valleys and passing through a great variety of climatic regions, which include the *puna*, the plains lying at an elevation of 4,700 metres, above which are the perpetually snow-capped mountain peaks up to 6,768 metres above sea level; the inter-Andean valleys which appear on descending to the coast; and the Amazon plains along the eastern slope.

The third territorial region, the jungle, extends from the eastern slope of the Andean cordillera down through intermediate areas such as the jungle fringe area (*ceja de montaña*) and eventually to the Amazon jungle.

PERU DURING PRE-COLUMBIAN TIMES

When the inhabitants of the central Andean areas became food producers after having domesticated animals and plants about 5000 B.C., they relinquished their nomadic habits to establish themselves on a more stable basis. Thus, they were obliged to build dwellings to serve as shelter, abandoning their caves to live on the productive lands of the valleys. The first dwellings of tree trunks and reeds were gradually replaced with stones or fragments of hardened earth cemented together with mud. Upon adopting a sedentary life, the primitive inhabitants of these lands set up communities which in time made notable progress in the development of

Peru, recently built wall using lumps of hardened earth. This method is still used in the valley along the coast, and probably antedates the use of mud bricks [*Photo:* R. Samánez Argumedo].

Pyramid built of mud bricks. The Huaca del Sol is 250 metres long by 50 metres high [*Photo:* R. Samánez Argumedo].

agriculture, construction of canals and building in general. Dwellings continued to be built in rudimentary form, but emphasis was given to constructions of a religious nature, generally pyramids, called *huacas*. The oldest ones were simply areas excavated in hard earth, lined with small cobblestones or with mud stucco.

Community activities fostered the development of these ceremonial centres, which acquired particular importance at Kotosh, built in 5000 B.C., and in the Andean area in general. No less important centres appeared on the coast in the areas of Casma, Huarmey and Lima. The buildings were gradually perfected and represented the only permanent type of construction of these ancient inhabitants of the central Andes.

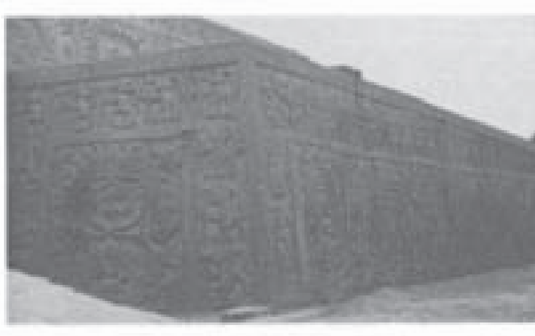
The use of *tapia* or consolidated earth and unburnt sun-dried mud bricks was the result of these circumstances, the latter appearing as a technical alternative for the construction of temples and other community buildings, above all in the arid and dry coastal area where the absence of rainfall made it a durable material. The discovery of cylindrical and conical adobes of different sizes leads one to believe that in its most primitive form the mud brick was used directly to replace the stones, and fragments of hardened earth which were gathered or worked by community brigades for the construction of ceremonial buildings. This hypothesis is more tenable than the idea that the mud brick appeared as the culmination of a process of technical development which in the case of Peru first centred on stonework, then progressed to methods for making such bricks, permitting perfect fits and the repetition of modular elements.

In the valleys of the Andean cordillera, agrarian technology gave rise to villages of more complex organization, with a dominant priesthood, and ceremonial centres of greater importance, built of stone and mud. This type of architecture responds to climatic conditions involving periods of intense rainfall which made it necessary to discard the possibility of using mud bricks for permanent buildings, although not for dwellings, deposits and other functional constructions.

About 1000 B.C., the Chavin culture established a great ceremonial centre employing these materials. It was an emerging state, dominated by a caste which controlled religious organization. Five hundred years later, regional cultures developed in the Andean cordillera, for example, at Tiahuanaco and Pucara. Later, military states appeared such as the Wari empire which extended over a large part of the highlands and along the coast. These groups built ceremonial centres and urban villages using stone and mud.

The Mochica culture achieved the foremost development of architraves based on sun-dried mud bricks. It flourished from 100 B.C. to A.D. 700. It continued the tradition of building pyramids based on superposed platforms reaching heights of up to fifty metres.

The city of Chan Chan, capital of the former Chimú Empire. It is the largest urban centre of mud-brick construction in South America.



The Huaca del Dragon, built in 900 B.C. in the Moche valley, near Trujillo. This pyramid, almost completely covered with decorative motifs, was restored in 1966.

These builders did not create urban centres but set up important villages round the temples. They had also a sufficiently advanced technology for the production of foodstuffs through the use of cultivated plants and domesticated animals, which led them to establish a complex system of long-term storage for the goods produced.

Techniques were developed to dehydrate, cook and toast the food and to store this material in deposits set up in specifically designated areas within the urban centres.

Centuries later, in the same Moche vally, the city of Chan Chan was built. Originally, it was known as Chimor, capital of the Chimu kingdom which flourished from 2460 to 1200 B.C. At the end of this period, it was conquered by the Incas. Chan Chan was the largest mud-brick-constructed city in the Americas, and consisted of eight citadels and a number of ceremonial pyramids, temples, public buildings and dwellings, located along broad walks crossing each other at right angles and surrounded by high walls, also of mud brick. The city had about 100,000 inhabitants. Its walls were covered with friezes and figures in relief, worked in mud, mainly mythological, allegorical or geometric representations of fauna.

In the construction of Chan Chan, millions of mud bricks were used, enormous areas of the walls being faced with mud in an effort without precedent in the history of the region. It is to be noted that the great walls which surrounded the cities were nine metres high and two and a half metres wide at the base. An important feature of these walls was the use of reeds or cane placed vertically, probably to provide greater flexibility when exposed to temperature changes and the lateral thrusts of earthquakes. The mud-brick walls were built in two parallel rows but without being bonded together, the interior being filled from above with earth or damaged bricks.

Archaeologists have discovered that the work was done in stages by different groups of subjects on the basis of some community labour scheme. History indicates that tributes in the form of produce or labour were particularly important in Ancient Peru. As to storage facilities, Chan Chan had a great number of deposits built of mud-brick, located adjacent to the citadels and surrounded by high walls. The deposits were generally rectangular, each side measuring from two to three metres, with a gabled roof and a single small door only one metre high. In Pampa Grande, another archaeological site in the Lambayeque Valley, with characteristics similar to those of Chan Chan, mud-brick construction or stone and mud-brick—it is possible to note the distinct sections which form part of the protective wall—demonstrate the construction stages following the system of tributes.

Successive sections were discontinuous and made of square bricks, some of them showing, in bas-relief, signs left there by their makers and differing in each segment. Paintings in pre-Columbian ceramics provide us with information about structural features which have not been fully preserved, such as the great monuments. The number and diversity of such representations provide general knowledge as to the different cultures, above all, those of the northern coast, from Salinar and the first phases of Vicus, to Chimu Inca, with greater variety during the Viru and Mochica periods. These observations and the study of archaeological remains make it possible to deduce that the pre-Columbian architecture of the central Andean region was characterized by extensive outdoor spaces formed by walls, terraces, rooms, plazas and streets. The architecture was not one of complex interiors. Rather, it was one of roofed areas of limited size whose composition made outstanding use of space, the mud-brick lending itself satisfactorily to such expressive needs.

The Inca empire appeared later, beginning its expansion in the first third of the fifteenth century, occupying an area of nearly 2 million square kilometres at the time of its apogee in the sixteenth century, before the Spanish conquest in 1532. The Inca empire utilized the knowledge and technology of the people it had incorporated into its domains. For example, the Incas took the urban solutions for the great walled areas from the Chimu kingdom, the orthogonal arrangement from the cities of the Wari and the techniques of working stone and the formal elements of architecture from the Tiahuanaco culture.

Inca constructions at Pancartambo near Cuzco: superposed mud bricks with gabled terminations that are placed above the stonework [*Photo:* R. Samánez Argumedo].

They used mud bricks as the main building element and did not consider it as a material of lesser rank, despite the fact that they had extraordinary and perfectly dimensioned stone walls as their form of architectural expression. Mud brick was used either as a complementary material along with stone or as an independent building element, both on the coast and in the Andean highlands. It was the general practice in Cuzco, the capital of the empire, as well as in other points of the highlands, to use mud bricks on top of the two-to-four-metre high stone walls, in order to reach the height of the roofing material and even to form the triangular section on which the roof rested. At the same time, there were stone buildings of different designs, finely executed, in which mud bricks were not used. So it was that some stone constructions were considered less important than others, such as the Temple of the Sun, which combind worked stone and adobe.

The Spanish chroniclers who recorded the customs of the Incas at the time of the Conquest, such as Juan de Betanzos, speak of

> bricks made of mud and sticky earth, in which a great deal of straw was thrown in, the straw being similar to the Spanish esparto grass; the mud and straw were kneaded in such a manner that the product was well made and solid. These were employed in construction in place of stonework, and their use extended to buildings and dwellings to attain the height and size required.

The mestizo chronicler Garcilaso de la Vega in his *Comentarios Reales* indicates that

> they make walls of mud bricks which they form in moulds, the way bricks are made here. Mud and straw are trampled together. They make the mud bricks the length they want the thickness of the wall to be. The shortest ones are a *vara* in length. They are more or less a *sesma* in width and about the same in thickness. They are put out to dry in the sun and afterwards piled up in order and left there exposed to the elements under shelter for two to three years so that they may dry completely.

When the Incas expanded their empire to the coast, they respected the existing places of worship such as the Sanctuary of Pachacamac, built of mud brick, to which they added their own temples, built of the same material but using their own formulas and methods. The most populated urban centre during the Inca occupation of the coastal valleys was probably the city of Cajamarquilla, situated near the Rimac river not far from the present city of Lima. At many other strategic sites they established administrative and control centres and occupied the villages in the region.

One of the sites which permits the best study of the characteristics of mud brick architecture, in view of its fine state of preservation, is the settlement of Tambo Colorado in the Pisco vally. The town surrounds a large trapezoidal plaza with quarters which were at one time covered with flat roofs, the absence of rain making gabled supports for inclined roofs unnecessary.

The walls of the rooms and the outside walls of the patios are made of mud brick resting on a foundation structure of angular stones. A fine coating of mud covered the walls, in turn characterized by trapezoidal niches, lending a marked Inca flavour to the area. The entire structure was painted in red and yellow, colours which to a large extent have remained unchanged.

Perhaps the most important example of Inca architecture using mud bricks was the temple of Wiracocha, near the locality of Racche, in the vicinity of Cuzco, at an elevation of 3,460 metres above sea level, with a rectangular area 92 metres long and 25 metres wide. It was at one time probably covered with a roof of more than 2,000 square metres, based on a large dividing wall a quarter of whose height consisted of stonework and above it mud bricks with a thickness of 1.65 metres and a total height of 12 metres. Eleven round columns extended along both sides of the wall. These, too, were of stone, with mud brick on top, supporting part of a massive wooden structure which formed the gabled roof of the temple.

At another remote location, in the town of Huaytara in the province of Castrovirreyna, there is another archaeological testimony of Inca construction with mud brick. It is a Catholic church built on top of a rectangular temple 26.5 metres long by 10.3 metres high. The wall of the north side retains its original gabled mud-brick truss structure, which is built on top of a stone wall as was the entire base of the temple. The truss structure was completed during the colonial period to give a different slope to the roofs when another use was given to the building.

THE PERIOD OF SPANISH COLONIZATION

After the Spaniards arrived in 1532, there came a period of forty years of wars of conquest and internecine struggles among the conquistadores which did not permit the construction of what might be truly called cities. Later, many mud-brick churches were built as places to preach to the Indians. Mud brick was a necessary choice for economic reasons, and most of the older churches, when reconstruction became feasible, were replaced by new ones built of stone or brick. The first churches to which reference is made generally had one single long nave with chapels at the transept, a gabled straw-covered or tiled roof, copied from the Mudajar Andalusian churches of the fifteenth and sixteenth centuries. Even the first cathedrals of Cuzco and Lima were modest structures of this type, which were replaced by stone structures when circumstances permitted.

Town architecture throughout the viceroyalty of Peru retained the Spanish tradition of stonework and mud-brick houses, with flat roofs along the coast and sloping roofs of clay tiles in the highlands, their layout generally centred round patios. When two storeys were built, wooden balconies were constructed to overlook the streets, accentuating Andalusian influences. Thus the use of mud brick, following pre-Columbian tradition, came to be identified with another form of architecture. Over the centuries, this architecture remained unchanged and, despite its fragility, withstood earthquakes, tremors and seismic thrusts which take such a toll on mud-brick construction.

As a result of earthquakes, the majority of the sixteenth-century churches built of mud brick, which had not been altered or reconstructed using other materials, disappeared. Examples of these churches are found only in the Peruvian/Bolivian highlands, an area of limited seismic activity.

It is important to point out that during the transition period, i.e. from the end of the Inca empire to Spanish colonization (1536–70), native traditions in construction continued, albeit incorporating certain Western features. Such was the case of the so-called Palace of Sayri Tupac, seventy kilometres to the north of Cuzco, a building of square design, stone foundations and mud-brick walls, whose formal expression is that of trapezoidal niches flanking a great doorway, and spaced openings and great niches—a purely Incan form of expression. The innovation took the form of the inclusion of wooden members as structural reinforcements for the mud-brick walls.

The solution consisted of seven members distributed over the seven metres, the total height of the walls, joining the corners where one wall met another. These reinforcements were placed solely at the two corners adjacent to the large entrance which required structural supports. Similar units are seen among the oldest colonial buildings in the city of Cuzco.

It may be noted that in the use of mud bricks during the colonial period certain changes were introduced into the pre-Columbian material. Dung was added during the process of moulding. Uncut straw from the *punas*, laid out in a spiral, was no longer used, being replaced by cut straw mixed with mud. Generally, the size of the mud bricks was reduced. In the highlands, dimensions were as follows; from 41 to 61 cm in length, 19 to 30 cm in width and 10 to 16 cm in height.

The material to which we have made reference was so widely accepted that it was not considered unusual to make use of it in the fortifications of Lima. In 1640, more than 4,000 metres of walls, bulwarks and wall sections were built using stone and mud brick. In 1687, Giuseppe Formento designed the fortifications for the city of Trujillo to defend it against possible pirate attacks. The walls were built using similar materials.

At the beginning of the seventeenth century, during the consolidation of the Spanish conquest in the Peruvian viceroyalty, the use of mud bricks had become generalized in the two main regions of the country; the coast and highlands. However, the frequent earthquakes resulted in a need for technical changes in design. Thus, after the earthquake of October 1609, it was

Colonial buildings with mud-brick arches superposed on stone walls built by the Incas. This demonstration of cultural symbiosis is frequently seen [*Photo:* R. Samánez Argumedo].

The mud bricks of the colonial period differed from those of pre-Columbian times in the manner of preparation and the use of formal building elements such as the arch [*Photo:* R. Samánez Argumedo].

Recent construction using mud bricks. This two-storey structure follows ancient building methods. Moreover, use is made of the only material within the financial reach of the majority of Peruvians [*Photo:* R. Samánez Argumedo].

decided to replace the groined and barrel arches planned for the cathedral of the city with a gothic or ogival vault. This measure was subsequently followed in the church and convent of Guadalupe in Pacasmayo and in the cathedral of Cuzco, for the intersecting vault had demonstrated itself to be more resistant to earthquakes.

Shortly afterwards, the use of *quincha*, or *bahareque* as it was known in Colombia, where it had been developed, was introduced. The method consists of using both wood and reeds, covered with mud, to build arches, vaults or partitions for buildings. This system had already been used by pre-Columbian cultures along the Peruvian coast, and was introduced in Lima by the Portuguese architect Constantino de Vasconcellos, who adapted it to a system of vaults which had been used before in Spain by the Jesuit order and subsequently introduced to Colombia in 1636. In the third quarter of the seventeenth century use began to be made of structures employing wood, *quincha* and stucco in the construction of vaults, arches and even the towers of churches along the coast. The system was extensively used in the eighteenth century in view of the greater flexibility of *quincha* during earthquakes and the almost total lack of rainfall along the Peruvian coast, permitting the use of such a vulnerable type of construction. Using this material, baroque architecture produced excellent results, both in churches and in manorial homes. Barrel arches and elegantly designed cupolas were built in this manner, permitting broad creative liberty in the interior areas in the use of wood, cane and stucco. Even in the cloisters of the convents, use was made of dummy pillars with square cross-section, supporting three-lobed arches, and was considered an acceptable solution.

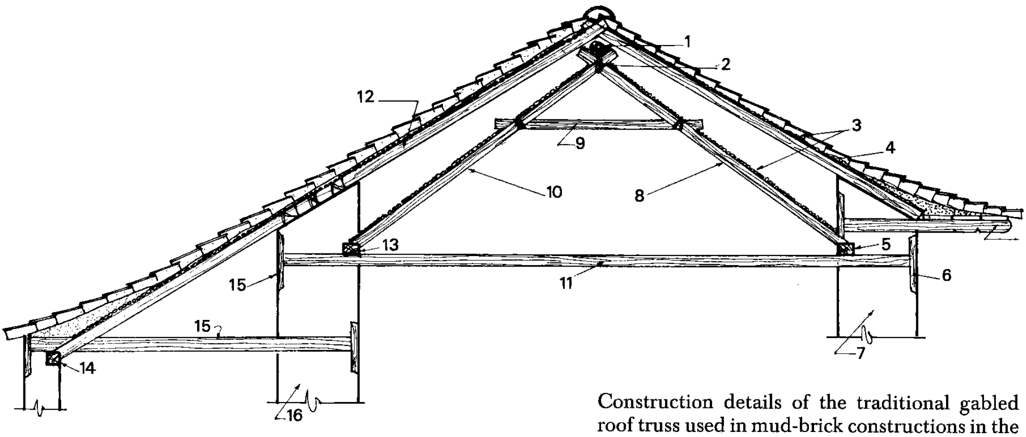
Its use was generalized for dwellings and civil architectural works. In combination, it was employed with the mud brick used to construct the ground floors of buildings. In view of its novelty, such methods of construction during this particular period of the Peruvian viceroyalty were the object of observations and commentaries from those visiting the area. In 1885, C. Stokman, an officer in the Swedish navy who visited the region during a diplomatic and trade mission, wrote as follows regarding the churches of Lima:

> The repairs made as result of the damages caused by earthquakes do not always follow the original style. Very little stone is used in the construction of these churches, being replaced by wood and reed, which withstand the tremors far better. There are churches that have suffered almost no damage despite sizeable earthquakes.

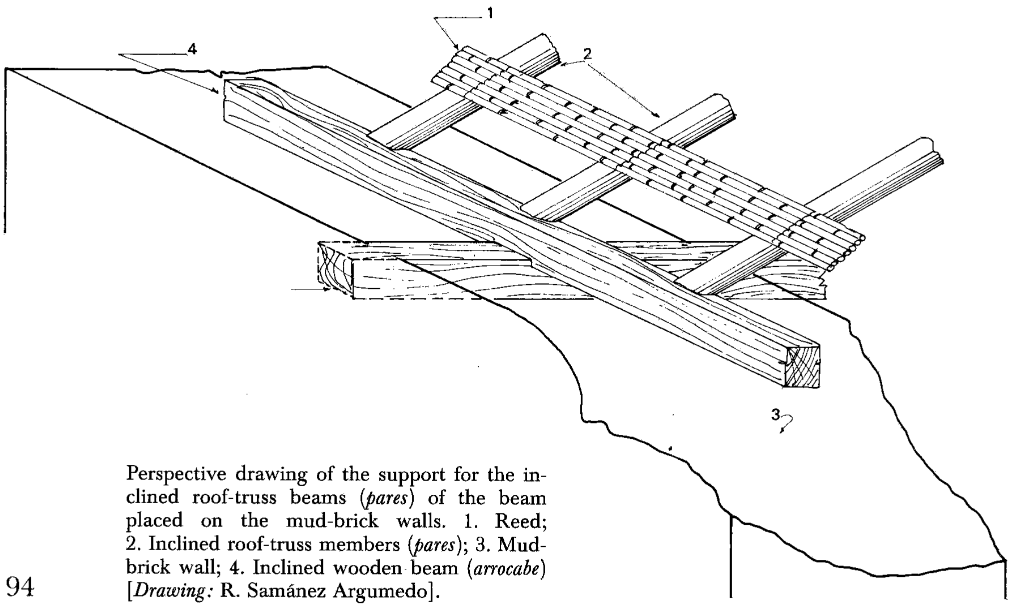
It should be noted that during the colonial period, the architectural profession was organized in the form of guilds and master builders, who transmitted the practical knowledge of their trade from generation to generation. Experienced builders used European treatises on architecture as a guide for important works, but took from them solely the formal aspects involved in coffered ceilings, cupolas, vaults, façades and plans for religious buildings. Guidelines for ordinary construction did not appear, however, in the abundant elementary and advanced reference material, with respect to the designs of famous architects, the art of surveying and the building of fortress and strongholds, which circulated. A few treatises dealt with the art of stone- and brickwork, but there was almost nothing on mud brick, *quincha* or consolidated-earth structures.

Craft tradition and the system of guilds and trade fraternities for the exercise of the building profession permitted, however, acceptable standards, following techniques taken from treatises, such as the *Carpintería en Blanco* of Diego López de Arenas, published in the seventeenth and eighteenth centuries. These served to inspire coffered ceilings, linings (*alfarjes*) and other more broadly used Mudéjar constructions such as those of triangular (gabled) roof trusses which appeared in all mud-brick constructions in the highlands.

In the many mud-brick constructions of the seventeenth, eighteenth and nineteenth centuries, particularly those of the religious buildings found throughout Peru, it should be noted that their deterioration has been due more to the poor quality and choice of the materials used in their construction than to the lack of skilled labour. Generally, damage occurred during periods of economic depression when communities demon-



Construction details of the traditional gabled roof truss used in mud-brick constructions in the Andean region. 1. Roof-ridge beam; 2. Joint tethered with leather; 3. Reed and mud facing; 4. Burnt roof tiles; 5, 13 and 14. Inclined beams (*arrocabes*); 6 and 18. Reinforcements to hold the tie-rod; 7. Mud-brick wall; 8 and 10. Roof-truss beams (*pares*); 9. Transverse roof-truss member (*nudillo*); 11. Tie-rod; 12. Upper beam; 16. Tie-rod [*Drawing:* R. Samánez Argumedo].



Perspective drawing of the support for the inclined roof-truss beams (*pares*) of the beam placed on the mud-brick walls. 1. Reed; 2. Inclined roof-truss members (*pares*); 3. Mud-brick wall; 4. Inclined wooden beam (*arrocabe*) [*Drawing:* R. Samánez Argumedo].

strated no interest in renewing and repairing the buildings which required attention, for mud brick is a building material which demands protection and constant repair.

THE SPECIAL PERU/UNESCO PROJECT

In response to a request for technical co-operation submitted by the Peruvian Government so as to permit the conservation and restoration of historical monuments in Cuzco and Machu Picchu and to promote tourism development in the area, Unesco organized a series of missions between 1965 and 1968 which evaluated the role that historical monuments and sites could play in the development of the tourist trade of the region.

Following the reports and recommendations of Unesco, the Peruvian Government established the Special COPESCO Commission to carry out studies on various topics, including the restoration of historical monuments.

For the study of historical monuments, a special technical assistance programme of Unesco and the Instituto Nacional de Cultura of Peru was established. At the same time, the COPESCO plan and specialized sectors of the government such as the Ministry of Transport, the Ministry of Housing and the National Tourism Enterprise carried out studies preliminary to a formal loan application which was filed with the Inter-American Development Bank in 1973, requesting funds to finance the improvement of the infrastructure of the region, the restoration and reconditioning of historical monuments and the construction of hotels at appropriate sites to permit a greater influx of tourists and foreign exchange, thereby leading to overall development of the area.

The target area of the COPESCO Plan was a strip about 500 kilometres in length in the eastern part of the Peruvian Andes, as previously described, between the Vilcabamda and Vilcanota cordillera, including the highland plateaux and the Lake Titicaca basin along the Peruvian-Bolivian border. It is a region characterized by mountain valleys such as Cuzco and the jungle fringe area near Machu Picchu, with elevations ranging from 2,400 to 3,400 metres above sea level. The remaining area is a highland plateau with an average elevation of 3,800 metres above sea level. Lake Titicaca is the highest navigable lake in the world, with numerous rivers flowing into it. Andean cultures developed there in the remote past and were based on the cultivation of tubers such as potatoes and the raising of lamoids such as the llama, alpaca and vicuña.

During the pre-Columbian period, this was the most densely populated area of the country. In addition to Cuzco, the capital of the Inca empire, there were important population centres such as Hatun Colla, capital of the Colla culture to the south, near the Lake Titicaca region.

With the founding of Cuzco by the

Spaniards, it became the most important settlement in southern Peru, with numerous Indian towns developing around it, their churches reflecting the period. In the first years of the Spanish conquest, the Jesuits founded groups of missions on the banks of Lake Titicaca and built churches which today are outstanding artistic expressions of the times.

The object of the joint Unesco/Instituto Nacional de Cultura of Peru project, was the restoration and reconditioning of the historical monuments in the Cuzco and Puno area. The Unesco contribution consisted of the provision of specialized personnel for restoration and methods of treatment to prevent the deterioration of building materials such as mud brick. The project was provided with suitable equipment and laboratories to carry out the additional tasks involved in the operations, and funds were earmarked for the training of local personnel by experts, with scholarships at specialized centres. The project began restoration work in 1975. Among its objectives were the following:

To establish the criteria governing the restoration and reconditioning of historical and artistic monuments and archaeological sites.

To prepare an inventory, catalogue and survey of the current condition of pre-Columbian and Viceroyalty monuments in the area, according to the priorities established by the COPESCO plan with the counsel of Unesco.

To complete the projects for restoration, consolidation and reconditioning of the existing historical monuments in the area selected, indicating the respective budgets and proper technology required for the different types of buildings.

THE HISTORICAL MONUMENTS

The initial programme of the COPESCO plan envisaged the restoration and reconditioning of twenty-seven archaeological sites and constructions of the Viceroyalty period, but was later reduced to twenty. The following is a list of the historical monuments built of mud brick which is intended to serve as the basis for a subsequent description of the experience obtained on the basis of the work performed:

Ollantaytambo. A colonial settlement was built over this Inca town. The ancient and remodelled Inca dwellings continue to be used as living quarters. There is an important ceremonial complex on one side of the mountain which is the main attraction for visitors.

Restoration work has been carried out here. The so-called 'Casa Horno', dating back to colonial times, which had been converted into a *cancha* or Inca dwelling by the addition of a second storey made of mud bricks on top of the stone walls of the ground floor now houses a wayside eating-house for tourists.

Yucay. This is an important pre-Columbian settlement which is outstanding for the stonework terraces used for cultivation running along the mountain slopes, the steps joining the terraces and the remains of buildings belonging to the same period. The palace of Sayri Tupac is located in Yucay. It is an important mud-brick building of the Inca-to-colonial transition period, which has been fully restored.

Pisac. This was a great Inca settlement, with urban centres and fortified areas. The majority of the archaeological remains still standing are of stone, but there are also some storehouses or deposits built of mud brick as well as vestiges of other similar structures, albeit in poorer condition. Experimental methods for provisional protection have been employed at this site.

The old Colegio de San Bernardo in the city of Cuzco, founded by the Jesuits in 1619, built around two patios, with stone columns on the ground floor and wooden galleries at the second level: this structure is entirely of mud brick and was abandoned due to the damages caused by the 1950 earthquake.

Its restoration begun in 1974 has been an excellent field for experimentation using traditional systems and modern techniques. The work was completed at the beginning of 1978.

Palacio del Almirante. This building represents the finest expression of the Renaissance period in the city of Cuzco, with a stone façade of exceptional quality and Mannerist influence. It surrounds a main patio with two floors of beautifully designed brick arches. The staircase is decorated with a faun and a stone lion. Exquisite coffered ceilings adorn the salons. As a result of the 1950 earthquake and the initial repair-work on this building, part of it had to be dismantled.

Its restoration, together with that of the Colegio de San Bernardo, represents a major achievement in the use of traditional materials, particularly of mud brick, the work was completed at the beginning of 1979.

The old hospital of the Betlemitas de la Almudena in Cuzco. This complex consists of two cloisters and a church. It had formerly been used as a city gaol and its state of deterioration was such that it required extensive work. It is a mud-brick building two storeys high with galleries supported by stone pillars and with brick arches at both levels. The second cloister is noteworthy for its architectural design based on great vaulted brick ceilings on all four sides, the church occupying one sector.

Above the vaulted ceilings, internal reinforcing arches made of mud brick have been installed, in order to avoid loading the vaults with the weight of the second storey walls.

In the restoration of the first cloister, experiments were made with different techniques for the mud-brick walls; these will be described later. The work was completed at the end of the first quarter of 1980.

The church of Canincunca, a rural building of relatively small size, with an important mural painting of the seventeenth century which completely covers the interior of the walls and the roof. The outside walls are of mud brick with an average height of six metres, and present structural problems. The presence of the mural painting required special solutions for the restoration work, which was completed in January 1980.

The seminary of San Antonio Abad in Cuzco. This is a large religious building consisting of a church, two cloisters and adjacent patios. The entire construction is of mud brick with the exception of the galleries, the doorway and the façade of the church, which are of stone. Careful work has been done in the structural consolidation of the complex which is to be used as a hotel.

The church of San Jerónimo, near Cuzco. This is one of the few examples of Renaissance churches of the sixteenth century still standing. The experience acquired in previous restoration work was used to restore the mud-brick structures in the chapels and towers, thereby assuring its conservation.

The manor of Clorinda Matto de Turner is an important example of seventeenth-century civil architecture in Cuzco and houses extraordinary mural paintings. Its restoration was sponsored by the Banco Central Hipotecario del Peru and use was made of the personnel of Unesco Project PER-71/539 to direct and supervise the work. Novel solutions have been employed to counteract possible seismic effects on the mud-brick walls.

The rest of the restored historical monuments, or those in the process of restoration, have other construction characteristics which do not involve the use of mud brick and are not, therefore, mentioned.

THE STUDY OF MUD-BRICK CONSTRUCTION

In order to devise an appropriate approach to the restoration of mud-brick historical monuments of the pre-Columbian and Viceroyalty periods, it was first necessary to determine what factors had contributed to their deterioration and in some cases had resulted in their destruction. The following factors were considered:

The effects of rain.

Temperature changes.

The condensation of moisture on the surface of the mud-bricks (along the coast, relative humidity runs from 75 to 100 per cent).

Stresses caused by seismic action.

Wind erosion accentuated by the abundance of sand along the Peruvian coast.

Salts deposited by sea breezes on the surfaces of the walls and saline efflorescence. Owing to the sand and clay used in the construction of the mud-bricks, salts come to the surface and subsequently deteriorate the material.

Other causes (the destructive effects produced by man, birds and insects).

In addition to being a deeply rooted ancestral tradition, the use of mud bricks as a building material has acquired particular importance during recent years since in the majority of cases it is the only material available to those wishing to have their own homes. Developments in construction and in related technical fields have been generally prompted by the need to improve housing quality with respect to materials, methods, as well as design aspects. These experiences, and the participation in the project of a number of specialists who have been working on the improvement of mud-brick design, permitted the extension of this approach to historical monuments made of mud brick, with special emphasis on improved systems for consolidation and conservation.

The research which state agencies and universities in Peru had carried out in the field of mud-brick dwellings was based on traditional construction practices, in an attempt to overcome the shortcomings of present building methods as to durability and behaviour of the material during earthquakes.

Pitch or tar was collected from oil seeps in pre-Columbian times and was used for the construction of dwellings and roads. During the colonial period the pitch was mixed with lime to form a mortar which improved its binding characteristics when used in stonework. At present, experiments with road asphalt mixed with earth to make mud-brick, or the addition of lime or cement to this material, have permitted the development of stabilized mud bricks with greater strength and higher impermeability.

Research designed to solve the problem of safety in mud-brick buildings during earthquakes led to experiments with low-cost reinforcing materials available in the rural areas, for example, bundles of reeds lashed together are used as internal reinforcing material, placed at regular intervals. At the Universidad Católica in Lima, tests have also been made with vertical and diagonal wires binding foundations and walls to a wooden collar beam, thus achieving a marked increase in strength against static forces. Studies were made of the behaviour of the walls, using mortar reinforced with cement, sand and lime, thus obtaining increases in static shear strength in the order of three times that obtained with mud mortar.

However, the problem of restoration of historical monuments imposed additional and quite different requirements, making it impractical to use this method straightforwardly.

For mud brick stabilized with 2 per cent asphalt and a compressive strength of 18 to 24 kilograms per square centimetre, its use in well-planned scientific restoration work would be limited to the replacement of missing parts. The original mud bricks of an architectural structure constitute a historical testimony which in principle should be preserved as far as possible. In the replacement of deteriorated mud bricks, the object is to produce a uniform result, and the mud bricks employed would not therefore be of marked contrast as to mechanical and physical characteristics since asphalt reacts differently in different climates.

For these reasons it was considered important to take full advantage of the course of this research to launch other studies addressed to the specific problem of the restoration of historical monuments. The original premise was that work would be done with the existing construction no matter what its quality might be, and that no attempt would be made to 'build' anything new.

For structural engineers, the greatest problem consists of determining rational design procedures to project the solutions which mud-brick construction requires, with a mathematical rigour comparable to that for other materials. The procedure considered most suitable was that of determining the strength of the basic structural element, the wall, against collapse, then applying a safety factor to obtain the final or permissible stress. Thus, the forces at wall intersections were analysed for the design of the bonding keys; and the stresses produced in the unsupported spans, to design lintels and caps. Moreover, recommendations were made as to building methods, repair of cracks, etc.

CHEMICAL TREATMENT OF SURFACES

At times, the material used for the construction of historical monuments has a testimonial value which demands conservation of the entire structure, whatever the damages due to any of the causes for deterioration previously cited might be. For the historical buildings in Peru, the pre-Columbian mud brick, at times covered with friezes and decorative elements, has just that exceptional feature. For its restoration, a chemical surface treatment was employed in 1975, using a 1:1 mixture of ethyl silicate and 96 percent industrial ethyl alcohol with the addition of 1 per cent hydrochloric acid acting as a catalyst for polymerization.

The application of this highly inflammable and toxic misture requires a spray pump, using one litre of the ethyl silicate per square metre. In view of the high cost of the ethyl alcohol and due to the fact that the ethyl silicate must be imported, the process is expensive in Peru, and its use has been planned solely for the most prized constructions. Trials were made at a number of important archaeological sites along the coast, such as at the Garagay *huaca*, a ceremonial complex of the Chavin period, built about 1000 B.C. and located on the outskirts of Lima. It consists of platforms, terraces and sunken plazas which are outstanding in that they bear polychrome friezes in high relief, moulded in mud. Experiments were also made at the Chan Chan archaeological complex, the capital of the Chimu kingdom, as previously described.

The silicate product was used at the palace of Sayri Tupac in Yucay. Trials showed that the ethyl silicate gives good results on mud-brick walls and on painted friezes, by hardening the surface and preventing powder formation on the mud surface.

The problems which have arisen in evaluating the trials are related to the proper use of the mixture and the necessary care required to avoid oversaturation of the treated surfaces, resulting in waterproofing which prevents subsequent treatment. Another problem is the change of colour, the mud brick taking on a slightly darker shade, but this also depends upon proper application.

In the case of painted friezes and mural paintings, it was considered sufficient to apply synthetic materials such as Primel, Mowilit, Paraloid and Calaton, which have been used with success on fresco paintings. The ethyl silicate may change the colours of these decorative elements, although by using extreme care and avoiding an excess of acid, positive results may be obtained.

According to recommendations made by the Unesco consultant on different occasions, the experiments with chemicals justify their general use in the conservation of pre-Columbian historical monuments, particularly along the Peruvian coast, according to the following procedure:

General cleaning.

Application to the upper part of the walls of a protective capping, consisting of a soil/cement mixture, obtained by mixing clay, salt-free sand, cut straw and Portland cement. The coat should be about two centimetres thick, and be applied with an irregular stroke.

Consolidation with ethyl silicate, after careful cleaning of the ornamental portions of greatest value such as friezes and decorative elements.

Consolidation with injections of Primal for eroded plaster and mural paintings.

At those sites where there are paintings, friezes and other elements of exceptional quality, use should be made of a shelter to protect them from the effects of wind, sunlight and abrupt temperature changes.

STRUCTURAL ASPECTS OF THE RESTORATION OF MUD-BRICK WALLS

Pre-Columbian mud bricks were generally made by mixing earth with uncut straw which was introduced spirally, as indicated in the quotation of the Spanish chronicler, Garcilaso de la Vega: 'The Incas made the mud bricks as long as they wished the thickness of the wall to be.' Mud bricks have been found measuring 45 to 110 cm long, 10 to 29 cm wide and 6 to 12 cm thick.

During the colonial period, the mud brick changed in composition, since cattle dung was added along with cut straw, with a reduction in the amount of gravel. Generally, in the highlands the dimensions were 45 to 61 cm long, 19 to

Preparation of traditional mud bricks with quality control. In five days and with four workers, it is possible to make 80 bricks measuring 60 cm long, 30 cm wide and 16 cm thick [*Photo:* R. Samánez Argumedo].

30 cm wide and 10 to 16 cm thick. The analysis of what we might consider a standard mud brick for the Andean zone of Peru, from the church of San Jerónimo near Cuzco, is shown in Table 1.

TABLE 1. Analysis of mud brick from the church of San Jerónimo, Cuzco

Probable date of sample	17th century
Granulometric analysis, limits of consistency	
Gravel and sand	68.47%
Silt	13.36%
Clay	18.17%
Compressive strength	
Maximum	14.87 kg/cm^2
Minimum	10.98 kg/cm^2
Bending strength	
Maximum	3.99 kg/cm^2
Minimum	3.12 kg/cm^2
Water absorption in 24 hours	15.29%
Capillarity, maximum rise in 24 hours	10 cm

The recommendations for the manufacture of the so-called traditional mud bricks stipulate a percentage of clay varying from 15 to 17, and therefore it is felt that the sample analysed must have come from a particularly clayey soil.

The Department of Civil Engineering of the University of Cuzco carried out a number of tests with mud bricks of traditional types from nine areas on the outskirts of the city, where they were the standard building elements. For comparative purposes, the results of the tests on one sample are shown in Table 2.

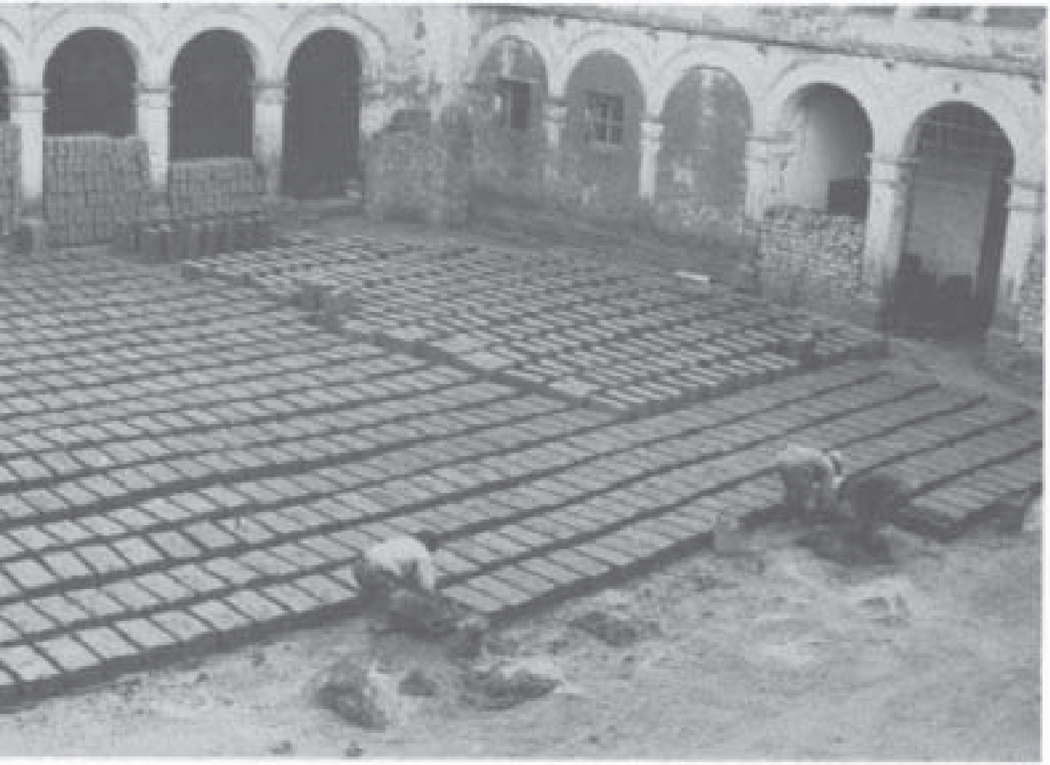
TABLE 2. Analysis of traditional mud brick used today in Cuzco

Probable date of sample	1979
Granulometric analysis, limits of consistency	
Gravel and sand	38.3%
Silt	43.8%
Clay	17.9%
Compressive strength at 28 days	
Maximum	19.15 kg/cm^2
Minimum	10.24 kg/cm^2
Bending strength at 28 days:	
Maximum	3.30 kg/cm^2
Minimum	1.25 kg/cm^2
Water absorption in 24 hours	19.79%
Capillarity, maximum rise in 24 hours	10 cm

These results and the respective comparison permit the following recommendations to be made:

The mud bricks which are now being manufactured in the city of Cuzco for the construction of homes are in keeping with the characteristics of the colonial formulas as to dimensions (length, 50 cm; widths, 25 cm; thickness, 10 to 15 cm).

Generally speaking, the characteristics of the old mud bricks have not changed with the years and are very similar to the new material which has acceptable strength under simple compression and bending.



One of the greatest disadvantages of the ancient mud bricks and the samples tested at the University of Cuzco was their poor resistance to moisture absorption (through capillarity) and to erosion. Moisture content appreciably influences their strength.

As to the ingredients used to prepare the mud mass, it is seen that a moderate percentage of gravel does not affect its behaviour; furthermore, the inclusion of straw, as long as it is neither brittle nor green, increases the flexibility and ductility of the mud bricks. The straw also increases bending strength and improves its resistance to water but slightly reduces compressive strength. The degree of compaction during the moulding of mud bricks influences characteristics as such strength and durability.

The amount of clay in the mix is one of the factors which most influences the strength of the final product. Another important matter is the proper procedure to be followed for their manufacture. Observations made during Project PER-71/539 resulted in the following conclusion as to the most advisable method: four workers are required to prepare eighty bricks in five days using the correct mud mixture. The sifted soil is mixed with water and left to set overnight. The next day, whole straw is added and the mass trampled, churning the mud, and the mixture allowed to stand another day. A fine layer of

Fitting new mud bricks into a wall in order to repair vertical cracks, producing a 'seam' [*Photo:* R. Samánez Argumedo].

sand is spread on the surface of the earth where the mud bricks are to be moulded in order to prevent dimensional changes. The wooden moulds have been previously soaked in water overnight. Once all of these steps have been taken, the mud bricks are moulded by firmly pressing the mud in the boxes, trampling it in with the feet. A rule is used to smooth the surface. Before removing the mould, cut straw is placed on the surface to prevent it from cracking upon drying. The mud bricks are lined up in rows and left to stand in the sun for five days, after which they are turned over and stood on their longer sides. At the end of fifteen days they should be turned over again, and stood on their shorter side.

After this operation, they are left to dry for thirty days in the sun. Therefore, the time of year for preparing the mud bricks must be properly chosen. Afterwards, they may be stored under shelter or used for construction.

MAIN PROCEDURES USED IN RESTORATION WORK

Generally, the restoration work on historical monuments made of mud brick is performed on the basis of the following steps in order to avoid subsequent effects on the structures:

Bracing of the walls, roofs and constant monitoring of stresses during the restoration work.

Reinforcement of foundation and

superstructure at both faces of the walls, alternately, ensuring complete bonding foundation for the two sides. The work is done on alternate sections, not exceeding one metre, avoiding continuous excavations which might result in inclination of the wall.

Reinforcement of mud brick walls to repair cracks and damage. The causes of the damage should be sought to determine whether they are due to transverse thrusts, lack of bracing or the settling of the foundations, to cite a few cases. The damaged mud bricks are removed and wooden blocks inserted, which are then replaced by new mud bricks, resulting in a sort of seam in the damaged section. In order to avoid crushing the mortar it is recommended to work two rows a day.

Placement of bonding keys. These are used because the safety factor for the first rows of the junction of the wall with the one perpendicular to it is very low. The keys consist of suitably anchored devices providing traction. Analytically speaking, the force acting is balanced by the resultant, in order to determine the length required for the pieces.

As a rule, the bonding keys should bear the weight of at least a two-metre-high mud-brick wall and be placed vertically every 150 cm. In the perpendicular walls, two parallel members of sawn wood of the proper length are inserted, crossed and joined at half the length of the beam, and the mud bricks are then set in place until the bonding keys are no longer visible in the walls.

In walls which are not to be dismantled, the placement of the bonding keys requires digging channels in the faces of the walls to the desired depth and position, then filling in the spaces between the mud bricks and the beams in order to confine the wood.

There are bonding keys consisting of a pair of iron reinforcing rods anchored at their ends, and others which take the form of wooden frames. The metal tension members are set in place after being painted with anti-corrosive paint and then covered with a mortar of cement and sand.

Generally, for lintels reinforcing unsupported spans, a number of wooden members are used. These may be round or rectangular. The characteristic of colonial construction in the area of Project PER-71/539 is that the lintels are inclined. As a rule, in restoration work, the prevailing criterion is that of retaining the original lintels, using a reinforcement above. This presumes that a triaxial force is acting on it with an additional load which may be the weight of the roof. Analytically, a calculation is made of the maximum possible length of the new lintel, bearing in mind the stresses and bending to which it will be subject.

Special operations to preserve portions of walls, when these are extremely deteriorated or when there are architectural elements such as niches, windows or decorative elements such as figures in relief or mural paintings. A number

Bracing and external supports for a section of wall having vaulted niches with designs in relief and paintings of a seventeenth-century altar-piece. Lateral chapel of the church of San Jerónimo near Cuzco [*Photo:* R. Samánez Argumedo].

of such operations have been successfully carried out with the object of surrounding the portion to be preserved with new mud bricks. The section may measure several square metres.

These special methods are employed to protect the surfaces of greatest value with coverings of rice paper and fine cloth, withdrawing the mud bricks row by row in the lower and side sections, carrying out the reinforcement operations as previously indicated. During this operation, it is feasible to correct variations in the plumb level of the wall using a hydraulic jack.

EXAMPLES OF SPECIAL SOLUTIONS ADAPTED TO RESTORATION WORK

Generally, in the restoration works in Cuzco, the system and procedures outlined above have been employed. However, there have been many cases in which the strength and stability of the walls required a special analysis of the vertical loads considering both dead weight and overload of the building as well as the action of lateral inertial forces due to possible seismic movements.

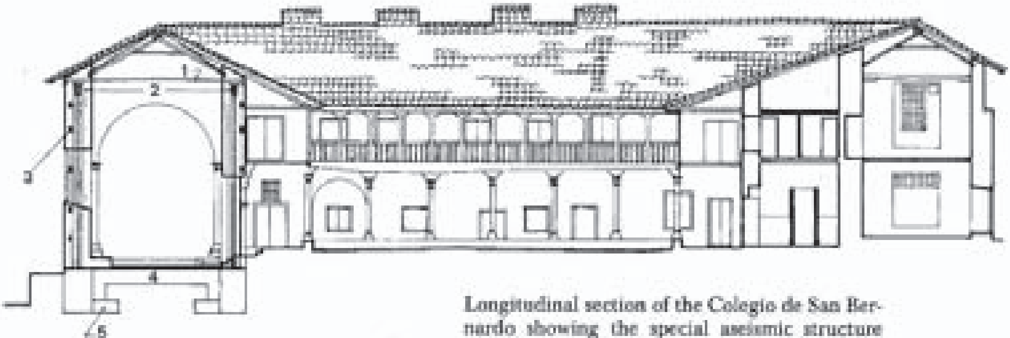
Those mud-brick structures which were subjected to operations more complex that the customary ones involved more or less the same construction features, with foundations and superstructures of stone blocks set with mud, walls of considerable length without intermediate structural bracing and wooden structures in the roof based on the triangular gabled-roof truss system bearing the weight of the burnt-clay roof tiles.

As a rule, the damage over the years was due to the following causes:

- Lack of proper storage of the materials for conservation work, which had been exposed to unfavourable climatic conditions.
- The destructive action of strong earthquakes or relatively intense tremors in 1650, 1905 and 1950.
- Structures affected by modifications made over the years, originally for the purpose of increasing or reducing the lengths of the walls and opening spaces for doors or windows.

Restoration of the Colegio de San Bernardo

The most important project involving special solutions was the church of the Colegio de San Bernardo, built in 1619 over the remains of walls of houses built between 1539 and 1600. The church has a rectangular floor plan and meas-



Longitudinal section of the Colegio de San Bernardo showing the special aseismic structure used for the church. 1. Wooden tension member to brace the gabled roof truss; 2. Centre-sill section beams of reinforced concrete joining pillars of the same material; 3. Wood reinforcements; 4. Foundation beams; 5. Pad [*Photo:* R. Samánez Argumedo].

Interior of the church of the Colegio de San Bernardo during the restoration work. Placement of a special reinforced-concrete structure inside one of the mud-brick walls [*Photo:* R. Samánez Argumedo].

ures 6.25 by 31.8 metres with mud-brick walls having thicknesses from 1.2 to 1.35 metres. The walls are 8 metres high resting on a stone foundation 4 metres deep.

The adjacent wall outside the Colegio de San Bernardo did not have intermediate bruttresses to help brace it, and greater stability was required to withstand the lateral stresses which might be caused by an earthquake.

It should be emphasized that during the extensive exploration of the church, niches and openings for doors and windows were discovered in the outside wall. Since these were part of pre-existing dwellings, it was desired to preserve them.

Before restoration work began on the wall, tests were made and the problems involved were discussed in detail. The best solution was considered to be the use of four pairs of columns and an independent pillar to preserve the integrity of the openings and the crypt, reinforced-concrete structures embedded at their lower ends on beams with foundation pads. Each foundation beam with the columns at its ends forms a U-shaped structure.

Previous trials at a number of other places to reinforce the mud bricks with columns, beams and reinforced-concrete bonding keys had given poor results due to the behaviour of the material. Therefore, the services of Unesco's Structural Consultant, Dr Ricardo Yamashiro Kamimoto, were requested to take into account the following characteristics:

The reinforced concrete structure should not be required to bear static loads since the wall alone sufficed for that purpose.

The reinforced concrete structure should respond solely in the event of the wall being subjected to lateral thrusts during earthquakes.

The following precautions were taken in order to overcome the unfavourable aspects pertaining to the union of the mud brick with the concrete.

The columns poured into the mud-brick structure were rectangular on the side facing the wall and octagonal towards the sides. This special design permits the reinforced concrete to support the mud-brick mass without striking it and without producing concentration of stresses.

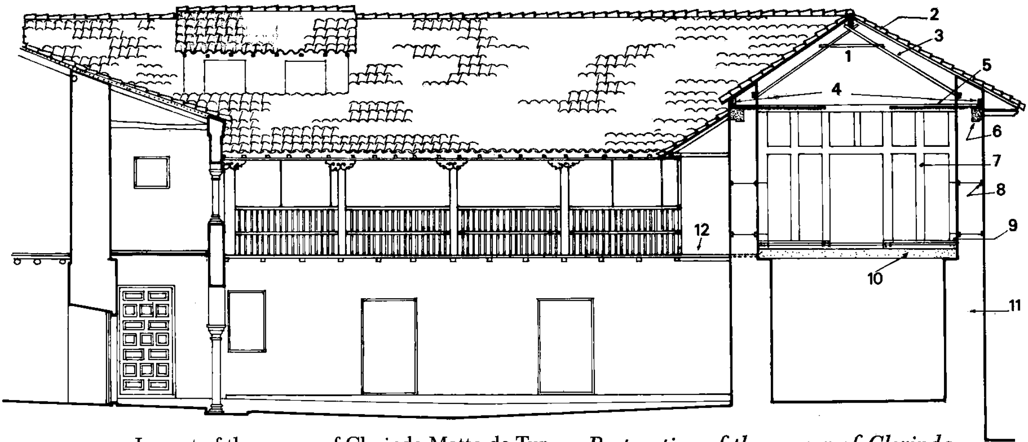
Experience has shown that the blow of the reinforced concrete against the mud-brick structure is due to the existence of a small space between the two materials. Impact effects have been reduced to a minimum through construction features which ensure firm contact between the two materials. This also guarantees the transmission of horizontal forces at the contact interface.

Among the construction features worthy of note is the fact that the columns had a cross section of 40 × 80 cm, being almost cross-shaped, receiving a coating of plaster 2.5 cm thick on both the faces in contact with the mud bricks. The other two surfaces in contact with the wooden bonding-keys were covered with sheets of expanded polystyrene

The same view of the church of the Colegio de San Bernardo upon completion of the restoration work [*Photo:* R. Samánez Argumedo].

5 cm thick. The wooden beams for bracing the mud-brick walls were joined to the columns through five 3-metre-long bonding keys distributed on both faces of the wall along its entire height.

Seismic analysis of the outside wall of the church of San Bernardo as it originally stood indicated a seismic-collapse coefficient of 0.053, equivalent to a grade-VI earthquake on the modified Mercalli scale. Failure of the structure would be due to excess pressure on the ground, followed by overturning of the wall. In the solution chosen, a seismic-collapse coefficient was selected for an earthquake of grade VIII on the same scale. To this, a factor was included for the design-rupture load, obtaining a seismic coefficient of 10 per cent.



Layout of the manor of Clorinda Matto de Turner showing some of the wooden structural diaphragms used to support the walls. 1 and 3. Roof with decorative paintings; 2. New roof added during the restoration work; 4. Wooden beam to distribute roof load; 5. Metal plates to join the reinforced-concrete beams to the diaphragm; 6. Centre-cill section beam of reinforced concrete; 7. Wooden structure (diaphragm); 8. Wooden reinforcing beams and metal pins to join the mud-brick walls to the diaphragm; 9. Wooden beam; 10. Concrete beam resting on mud-brick wall; 11. Mud-brick wall; 12. Wooden gallery [*Drawing:* R. Samánez Argumedo].

Restoration of the manor of Clorinda Matto de Turner

This is one of the best examples of seventeenth-century civil architectural works in Cuzco and was restored for use as the main office of the Banco Central Hipotecario of Peru. It required the reinforcement of the load-bearing structures in the walls, mezzanines and roofs, to prevent damage to the mural paintings which profusely covered the walls and inner surfaces, the gabled roofs resting on a triangular truss.

One of the wings of the second floor had very long rooms without intermediate bracing. Due to the presence of mural paintings it was impossible to solve the problem by using intermediary walls to divide the salons. Therefore, two thin partitions made of reed and mud (*quincha*) which ended at a painted roof truss were replaced by two flat wooden diaphragms resting on a beam of reinforced concrete at the level of the mezzanine, in turn supported by the existing mud-brick wall.

The diaphragms were joined to two reinforced-concrete beams running perpendicularly along the upper part of the wall and were used to provide access to the upper part of the wall that was to be braced, facilitating its attachment to the diaphragm and to the other parallel wall.

The cross-section of these cill beams was designed in such a manner as to permit greater adherence to the mud-brick walls and a greater lateral surface of contact. The beams are supported by the walls in such a manner that they cannot damage the mud structure in the event of an earthquake, being separated from them by a thin plaster surface.

Hospital of the Betlemitas de la Almudena

Different and special solutions were applied to this eighteenth-century complex in the restoration of mud-brick walls which had been severely damaged. The most outstanding operations were those involving the repair and straightening of a section of wall corresponding to the second level of the first cloister. It was a portion of the wall with mural paintings, forming part of a very damaged section which had moved from its original vertical plane.

After protecting the mural paintings, the wall section was straightened using levers and mechanical traction, and after being placed it in its final position it was bonded in place and restored using new mud bricks until the original height was reached.

Another solution worthy of note was the unsupported span of the façade of the historical monument, which required greater stability against possible lateral thrusts in view of the fact that the rooms on the second floor were very long. The method consisted of inserting bonding keys in the form of a 'T' with two parallel beams crossing at floor level on the second storey in order to brace the outside walls by means of those perpendicular to them. A mezzanine was also added using beams of sawn wood on top of the old round-wood beams, which were left in place since they were covered with moulded mud to give the appearance of a coffered ceiling.

A double wooden beam with a 15 cm cross-section was placed at the level of the upper part of the outside walls forming a collar for the entire area. This double beam, consisting of overlapping members, secured with iron clamps and vertical wooden wedges introduced into the wall, bore the weight of the upper rows of mud bricks and the gabled truss roof. This permitted a structural bond which prevented inclination of the walls.

The church of Canincunca

At this rural church near Cuzco, the outside mud-brick walls were 110 cm in thickness, with an average height of 6 metres and a length of 21 metres without lateral bracing. One of these walls was slightly inclined outwards, possibly a long-standing condition since there were already buttresses to counteract the resulting thrusts. A new parallel structure was added with the same object in mind.

The aim of the restoration work was to stabilize the wall, which was completely covered with mural paintings on the inside, by removal of the added wall. The foundations were reinforced with mortar consisting of lime, sand and cement and the two old buttresses, of which evidence had been discovered upon removing the attached wall, were restored. In accordance with the results of the structural study, another two new supports were added.

Through proper bonding of the wall and the five buttresses, effective lateral bracing was achieved for the inclined wall, with the proper distribution of bending movement to cover the possible effects of lateral loading during earthquakes.

To give greater strength to the junctions of the aforementioned wall at the angle formed with the belfry, which was also made of mud brick, wooden bonding keys were inserted every 1.5 metres along the vertical with double members 7.5 × 15 cm crossing at wall junctions. It was necessary to establish a design for the clerestory in order not to touch the ancient gabled truss roof the ceiling of which was covered with frescoes. To prevent the thrust from the original roof and the new roof placed on top from causing horizontal stresses to the walls, four metal tie-rods were set in place and concealed by the old wooden tension members which crossed the nave of the church.

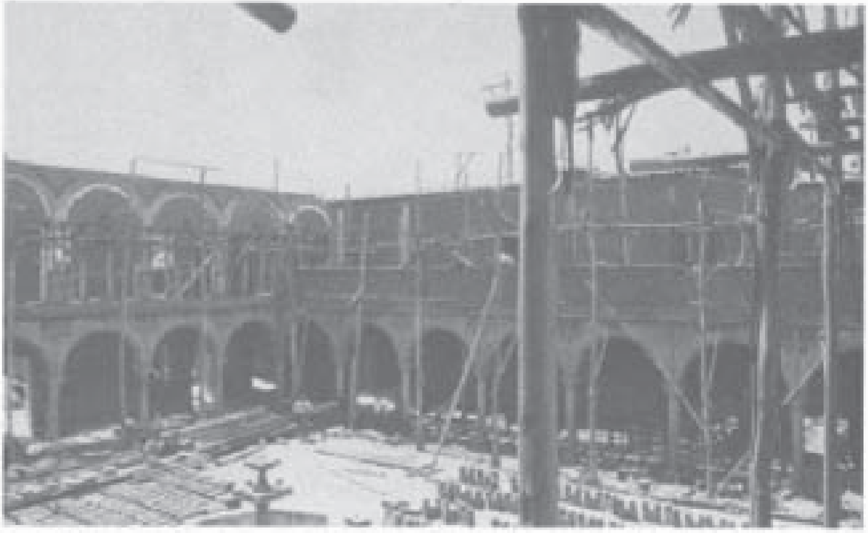
CONCLUSION

These examples of the restoration work performed, and the photographs and drawings which illustrate it, all testify to the splendid work which has been carried out in Cuzco during recent years, until the end of 1979, with the assistance of Unesco.

One of the most important conclusions which may be reached from this work on historical monuments is that, with local technology and limited resources, it is possible to overcome nearly all restoration problems.

Although the restoration of mud-brick buildings described in this study constitutes a part of the general problem confronted, and perhaps its most important aspect, there are nevertheless other working areas involving structures in other materials which necessarily took up the time and efforts of the technical team in charge of the project.

These studies were made possible by the Unesco/Instituto Nacional de Cultura special project, but since it was terminated in 1979, opportunities to carry them further have been drastically reduced.



Replacement of the mud-brick wall to close one of the sides of the patio of the Palacio del Almirante in Cuzco. To enable the wall to withstand later stresses during earthquakes, it was reinforced with vertical wooden beams. Note the 'U' shape of the mud bricks which were specially made to hold the beams in place [*Photo:* R. Samánez Argumedo].

The same view of the patio of the Palacio del Almirante in Cuzco, after completion of the restoration work [*Photo:* R. Samánez Argumedo].

'Appropriate' technology?

Alejandro Alva and
Elizabeth A. Chapman

INTRODUCTION

The concept of 'appropriate technology' has been of interest to both authors for many years, primarily because we have found it to be a misleading one. It is identified with the prevailing 'progressive' position concerning the transfer of technology. Recently it has come to mean, *inter alia*, a certain relationship between the level of technology which is made available to an underdeveloped country[1] and the degree of change in traditional life-style which results from it. This meaning has grown out of an awareness that wholesale 'modernization' leads to the disapppearance of traditional building skills, customs, and vital social relationships. The term seems to imply that there is a level of technology, somewhere between 'high' and 'low', which when employed by people in underdeveloped countries will interfere minimally with existing culture and tradition.

Through their diverse backgrounds and experience the authors have come to criticize this implication of the term on the grounds that it condones a certain destructive process, regardless of the level of technology which is transferred. The process separates two components in the natural development of culture which are essential for its evolution. By simply supplying a solution, a machine which enables the problem to be solved, or a material which in some sense more adequately solves the problem, an important 'bond' is loosened. The bond is the relationship between the development of the solution and the order and meaning which everyday activities are given as a result of their role in production.

In seeking to identify the essential ingredient of a successful relationship between technology and tradition, it became clear that we had to re-evaluate the criteria for 'appropriate technology'. It is not a question of solving the problem in the most expedient or sophisticated manner, or of producing something which is stylistically similar to the traditional technology. Rather, the question is whether the solution draws the people who are using it into a rela-

1. The use of the term 'underdeveloped' is the result of careful consideration. The term 'developing' implies a concept of development that we do not share—it places the problem in a linear perspective, as if each country or group started at the same moment and in identical conditions and as if all should progress towards a certain 'model', perhaps that of the so-called 'developed' country. We believe that the word 'underdevelopment' expresses better the close relationship between the contrasting conditions in the countries involved, i.e. the process of 'development' has generated underdevelopment.

tionship with the materials they live with and the process that is used to refine those materials.

We have identified four aspects of the relationship between technology and tradition. These are presented below in four 'pairs' of cases. In the first two, we propose to evaluate the role of *materials*, contact with and exposure to their characteristics, and the way in which the relationship to them enables the user to understand (or prevents him from understanding) the resulting technology. In the second pair, we deal with *the transfer of technology* as a form of education, and the effect of an imposed solution on the control which a craftsman has over his work. In the third pair, we consider the idea that *physical organization* of living and working areas of the community makes possible the overlapping of activities and the integration of function. In the fourth set of studies we are concerned with 'style', how it flows from technology and the role it serves in tradition.

Once we had outlined the criteria for the successful technology/tradition relationship and realized it was applicable to various underdeveloped countries, we had to ask ourselves if developed countries did not also need the same close relationship. To understand the parallel with the situation in an underdeveloped country it is essential to see that materials, labour, education, physical organization, and style, exist in an ecosystem. In the Andean region, the contact which occurs between the individual and his local material and technology is extended through a process of education, i.e. through normal contact with other members of the community. The forming and drying of mud brick, for example, take place in a public place where traditional technology can be passed on from an older, more experienced person to a younger one. This simple education nurtures another generation of individuals who can sense the characteristics of the local materials. There is no element of academic or theoretical study, the student is as close as he can be to understanding and learning in the same way as the craftsman does. But to see how and why this educational process occurs, it is important to recognize the significance of physical organization of the environment. In these villages the production of mud brick is not relegated to a separate area, external to the living areas. The living and working areas are in such proximity that education through exposure is part of the daily pattern.

In the following pages we hope to demonstrate that the identical phenomenon can occur in a developed country. Hence the 'level' of technology is relatively unimportant. This raises some questions about what development is, if it is not the ever-increasing availability of sophisticated technology.

MATERIALS

The first illustrative example is that of a chapel in the village of Challapampa (Titicaca Lake, Andean region). The people of the community had been per-

Challapampa villagers collecting straw for roofing [Photo: A. Alva].

suaded by the priest to demolish the building so that a new one could be built. At the same time, a restoration programme was being carried out in a nearby town. We were asked to give advice on the new construction, being the only engineers in the area. When we arrived at the site, the straw roof had been taken off and the sacristy completely removed. It was obvious however, that the chapel dated back to at least the sixteenth century. As there remained a few individuals in the community who were against destroying the old chapel, we approached the project with the idea of possibly restoring the existing structure rather than constructing a modern one in its place.

The first step was to protect the future of the chapel by arranging for the national authorities to recognize it as a historical site. The next was to meet with the people of the village to see what interest there was in collaborating on the work. The men in the town knew the traditional mud-brick construction techniques, the carving methods used in the stone details and the old system of straw roofing. It was understood that the materials would be those available at the site. In exchange for the work contributed by the citizens of the town, it was agreed to have the paintings inside the chapel restored at the restoration centre in the next village. It was after the people of Challapampa visited the restoration centre and saw the care with which a church of the neighbouring village was being treated that they took an interest in preserving their own

Challapampa Chapel, restored; interior view [*Photo:* A. Alva].

building. With a new sense of pride, the entire village felt the need to restore the chapel and the work began.

The area around the chapel was converted into a mud-brick production yard where the earth and water were collected, mixed, formed and dried. A team of men worked on the bricks, the production of new interior detailing, and the stone paving for the courtyard. It was during the process of making the capping tiles that the clearest benefits of the production system became evident.

The kiln for the firing of the clay tiles had not been used for many years, and had to be modified and fuelled with available material. A long period of trial firing occurred in which the resulting tiles were substandard because of inadequate temperatures in the kiln. The range of materials available as fuel was quite slim, and did not include wood or petroleum products. Many materials were experimented with in an effort to find one which might create greater heat. Finally, sheep dung, which was readily available, was found to burn very well. After many hours of hard work, tiles of great hardness could be produced. It was an exciting accomplishment for the workmen. That feeling contributed in an important way to their enthusiasm for the completion of the chapel.

To understand the significance of this situation, it was helpful to us to pose a series of questions as a basis for discussion.

Questions

1. What is the process by which technology is evolved and improved?
2. How does involvement in the devising of a solution increase its significance in an individual's life?
3. How does he or she come to take pride in workmanship?

Discussion: suggested responses

1. It impressed us that a technique for the improvement of firing tiles was revived during the process. That kind of advancement is an important part of the trial-and-error experience in the evolution of technology, and it seems important to note the context in which it happened.

In the process of refining local materials to produce elements which will finally serve in the production of a solution, people develop a familiarity with the characteristics of the materials. The ideal proportion of soil and water in the adobe mixture can be sensed by the workman who is familiar with the process. The size of bricks and the design of tiles have been evolved through trial and error over hundreds of years. When an activity requiring the use of local technology is carried out, the person who understands every step of the procedure can operate with confidence and responsibility.

2. This procedure began before the construction of adobe blocks for the chapel. The familiarity with the mechanical aspects of straw, which one develops while preparing it for livestock, serves as a reference for selecting it to reinforce or insulate the mud brick. This kind of understanding places the available materials in a relationship with the everyday activities of the people.

This relationship is one in which there are overlapping meanings given to the physical world, meanings that derive from their usefulness to people. Because he must evaluate this, the individual is at the centre of the activity; there are no intervening machines. Personal endeavour and past experience combine in the significant image which the environment comes to have. This was one of the clearest aspects of the study concerning the chapel.

3. Once the responsibility for restoring the chapel was accepted by the people of the village, the process was incorporated into the traditional value system. Part of the sense of being responsible meant giving the activity significance in terms which had meaning for the people involved. Before any

work could begin, a ritual of killing a llama and throwing the animal's blood on to the building had to be performed. This ritual is in fact a kind of re-interpretation of the activity in the language of the traditional customs. This re-interpretation created the possibility of taking personal responsibility for the workmanship and having pride in the final accomplishment.

It seems clear that the work involved the people in routines which were satisfying personally, in terms of achievement, and socially, in terms of the co-operation that was required. The balance of an optimum of available materials, and a meaningful co-ordination of individuals, proved to be a significant factor.

The second example is derived from the general direction in which mechanical activities have developed in the context of daily living. Today, it is not uncommon to be unable to open a window, to put a frozen meal into an oven and push a button before eating, or to obtain hot water by turning on a tap.

The activities associated with these same purposes were very different only a short time ago. Water was pumped up by hand, the human arm served to operate a lever and the water came out on alternate strokes. The process was clearly the result of a kind of hydraulic mechanism. Although the concept might be thought of as sophisticated, the amount of pressure required and the quantity of water produced, and the sense of water entering the pump on one stroke and coming out on the next, all combined to make the process understandable.

Similarly, a short time ago, the preparation of food was a much longer process, which included seeing an animal hung in a butcher's shop, or perhaps raising it as livestock. When finally a meal was eaten, each member of the family had perhaps participated in some way.

The example of the window can best illustrate this. A short time ago a window might have been composed of: (a) an outside shutter; with handles and latches to secure it when open or closed; (b) an inside sash which swung or pivoted open and was adjusted; with notches in the frame and a metal rod extending from the sash, and (c) inner shutters which might have had smaller openings to allow air but no light, or air and light but no view, or all three. With all these combinations, the technology of the window placed the user in the position of evaluating the conditions outdoors, the weather, the view, and the wishes of those inside. The more highly developed system consists of fixed glass and air-conditioning. The user has a relationship with the window resulting in fewer alternatives and less involvement in the business of defining enclosure.

Another more subtle change occurred as a result of this new technology. The need to touch the frame, to work the latches along its edges, and to observe the simple mechanics of the restraining rods and the wooden frame, has disappeared. In its place there is a more remote activity which in itself is no more characteristic of opening a window than it is of starting a car or turning on a light.

This lack of contact with the nature of the materials used in the construction of the window, combined with the more sophisticated mechanism which disguises its operation, removes the user from one source of education about the environment. When the window leaks, it is possible that the person living in the building understands the sealants, and the glass-setting procedure. But it is unlikely that in a specialized economy the same person can also fix the car, the television set, the roof and the water heater.

Questions

1. What pressures lie behind the development of improved technology?
2. What has the separation of the evolution of technology from the lives of users meant, for the quality of the resulting solutions?
3. What characteristics of an object inform the user as to its material and construction?

Discussion: suggested responses

1. In this context, the evolution of technology proceeds outside the arena of use, under the supervision of an engineer in the confines of a laboratory. The trial-and-error technique of continual improvement, which in the Andean region resulted in unconscious adaptation of highly sophisticated engineering, is replaced by the research developments of a corporation. Such research inevitably represents the economic interests of the corporation concerned. Ultimately it leads to the production of materials which serve their interests in the most expedient way, rather than meeting a need or being appropriate to a place. In fact, it is no longer need which creates pressures for the development of technology.

2. While the tolerance of materials has been increased and new materials have been invented, their utilization has not served to improve our understanding of their qualities, construction or structural properties. The great achievement of being able to make any material perform a function of which it does not seem capable is in fact not an achievement at all. It is the apogee of our confusion over the place of materials, their characteristics and their workability.

3. The understanding which we might have derived, given the possibility of assembling materials in a manner representative of their capacities, allowed craftsmen to incorporate materials with a sense of responsibility and workmanship, and to produce mechanisms which can respond to the subtle variations in the demands we make upon the environment. This kind of understanding can only result from solving the technological problem ourselves and experiencing the physical and visual repetition of that experience. It is through this channel that an individual can come to

understand how to control technology.

The discussion of these questions is linked to the consideration of education and how technology is transferred. It is clear that the best form of education is one which is most closely relevant to actual experience. The role which technology has come to play in developed countries is directly related to the fact that education is remote from actual experience.

TRANSFER OF TECHNOLOGY

The first case involves a more general evaluation of a recurrent problem in the Andean region, which is symptomatic of a larger international dilemma. The traditional mud-brick structure is roofed with clay tiles. The clay used to be selected from local earth and produced and formed into tiles in large batches when new buildings were constructed, or in small batches when a roof needed repair work. The process is known to most of the members of any village, passed on from craftsman to observer by exposure to the work as it is done. An opposite process started when oil was discovered and the population became involved in an economy of imported products. Tin roofs became available as a replacement for the original tiles. The tin roof was sold as having many advantages. It was heralded as a transfer of improved technology.

After several years of the new tin roofs, certain problems arose which were by now beyond the capacity of the towns people to solve. When the roof developed a leak, the equipment which was necessary for the repair of the metal was not available. Because the units had been manufactured in a factory, outside the context in which the people of the town could observe their production, nobody had any idea of how to work the material. The general response was to buy a new tin unit and discard the old deteriorated one. Whereas formerly the people had control over the technology involved in their environment, they were now dependent on the exports of another economic system. By this means they were subjected to the increases in prices which the exporting country might impose and the economic weakness which such a dependence creates.

In addition to the above problems, there was a more subtle but more far-reaching one affecting the traditions of the people. The production of clay tiles involved several intermediate steps including collection of materials, clay, water and straw, as well as the forming and drying of the units. This was a public process in which everyone took part, it constituted an education for younger people in local technology. Each one of the steps had activities associated with it, which in turn gave more meaning to the final product and made the production process more comprehensible. The combination of the steps of production, the meaningfulness of solving a housing need, and the visual and physical repetition of the activities, manifested itself in the character of the culture. The transfer of the tin-roof technology caused these steps to be circumvented, a fact which has also manifested itself in the character of the culture.

We had to consider the ideas which promote the transfer of technology, which is such a threat to tradition.

Questions

1. Can technology be transferred?
2. What is the difference between transferred technology and local technology?
3. How does a transfer of technology affect the traditions of workmanship and pride which an individual feels?

Discussion: suggested responses

1. Consider carefully the idea that technology can be transferred. It implies that there is nothing more to technology than the solution itself, and that once a developing country employs the equipment, a thorough revolution in capabilities can advance the standard of living.

To see the misconception behind this, it is necessary to think about what technology is. It is important to ask whether the process of producing the solution to a problem is not as important as the solution itself. Technology belongs to all eras of civilization as a capacity to bring together elements of the environment into a tool which facilitates some further goal. The interpretation of technology upon which a 'transfer' is based ignores the first and perhaps the more important half of the process.

2. The example of the tin roofs demonstrates that a transfer of technology is the imposition of a 'black box',[1] a magic solution, which works, or does not work, for unexplainable reasons. The magical aspect of the solution serves to put the user in the position of the dependent and secondary co-worker. The sense of responsibility and control which the person who created the machine would have are not available to someone who simply follows its rules. It is in this sense that local technology and transferred technology are so different.

The fact of responsibility is significant to the role that the individual has within his community. While responsibility does not necessarily mean social freedom, personal accomplishment and self-determination are offered through the control of the environment which occurs as a consequence of participation and responsibility. By being placed in the position of having no alternative but to accept imported tin roofs, the personal rewards of having control over the environment are lost.

3. The second 'transfer of technology' example is a comparison of the same technological information as it is transferred through the educational institutions by a theorist, and as it is presented after site observations by someone with many years of experience. A recently published paper quotes two expert sources of information concerning how

1. Ignacy Sachs in an interview published in *Le Monde*, 10 February 1980, p. 13.

materials and constructions react to earthquakes.[1]

Professor N. N. Ambraseys is a distinguished seismologist who travels to the site of an earthquake and reviews the factors influencing the degree of actual damage. He observes that all types of construction are damaged and that the significant factor is not whether the construction was brick, concrete or adobe, but how careful the construction had been.[2] This observation provides us with valuable information in several ways. First, it tells us that workmanship and the conditions which promote good workmanship are important for increasing the durability of the construction. It tells us also that the modern materials, which are thought of as technically stronger, and the ancient adobe, which is thought of as technically weaker, take on different characteristics depending on how well they are used. Professor Ambraseys reminds us that modern materials are often not utilized with equally modern construction techniques.

On the other hand, the Mercalli scale, used for earthquake magnitude evaluation, ascertains earthquake damage according to the type of construction prevalent in the affected area. Criteria are ordered from least to most vulnerable, modern construction which is reinforced, modern construction which is not reinforced, and mud-brick construction, which is simply termed 'weak'.[3] The Mercalli scale is misleading to the extent that it promotes the idea that it is the material alone which is responsible for the durability of construction, and that adobe by its nature is a bad material to use in an earthquake zone.

Questions

1. What is the significance of the discrepancy?
2. What is its cause?
3. How is technological education which is learned from a remote position related to education which is learned in the context of the work?
4. Can education direct development?

Discussion: suggested responses

1. The discrepancy between these two sources of information is significant in two ways. First, proper construction-damage prevention should be based to some extent on workmanship; but the Mercalli scale implies that a sound solution is to replace 'weak' mud-brick buildings with modern reinforced concrete. It is possible, then, that the limitations of the Mercalli criteria will aggravate the problem rather than help to understand it. Secondly, by referring to adobe as 'weak', Mercalli may have influenced many of his readers to pass on misinformation about the attributes of

1. Bernard M. Feilden, *Earthquakes and Historic Buildings*, Rome, ICCROM, 1979.
2. N. N. Ambraseys, 'Seismic Environment. The Skopje Earthquake of July 1963', *Revue de l'Union internationale de secours*, No. 5, Sept. 1966, p. 1–20.
3. Feilden, op. cit.

the material and the construction techniques. By this means, values about the worthiness of living in adobe buildings are changed. What in fact if a material associated with 'poor' countries becomes one which is also thought of as being inferior structurally.

2. Ambraseys and Mercalli can be seen to represent two different types of education, transferring technology in two different ways. In the first instance the information which is related comes from an education through direct observation. In the second, the information comes as a result of a theoretical projection.

It was essential for Mercalli to rely upon these existing capsules of knowledge because he was physically removed from the situations which would have allowed him to make accurate observations. He was not able to modify his findings to reflect the conditions of the communities for which his information is intended. All this results in a form of education that, when transmitted to, say, a student of structural engineering, may result in his carrying back with him to his native community—in which adobe construction is the norm—the belief that the progressive and intelligent methods of building are all in concrete and that adobe represents a backward and inadequate construction technique.

3. As education ceases to be a community activity extending beyond even the realm of local schools, and becomes geared to the global community, the underdeveloped countries are influenced by the simplified categories created by the misunderstandings of the developed world. Traditional methods of construction are being abandoned because the people using them have heard that they are something to be ashamed of, something which reflects their ignorance and the fact that they are underdeveloped. When the educated person returns home and builds a new concrete house, with a hired contractor, perhaps, a powerful new influence is injected into the traditional educational system of exposure, observation and contact with materials.

While it is clear that adobe structures could never achieve the height of a skyscraper, it is not so clear that the new construction excels in many other ways. The new building may age badly or create social problems. Its structure is governed more often than not by profit considerations.

4. The point is not that improvements sought after through education are negated by the economics of the developed world, but that the latter is so highly specialized and its education is based on such deep divisions between different realms of life. In the developing country, the overlapping realms serve to inform and check one another; education is derived from the activities of other realms. A type of remote or theoretical education which typifies the system in developed countries, has allowed one aspect of the society to dominate through its impact on the quality of the physical environment. It

is for this reason that the misunderstanding of the implications of technology transfer leads to irresponsible solutions.

PHYSICAL ORGANIZATION

How does physical organization of the village and country influence tradition? The proximity of human settlement to the work area creates demand and interlocks socially to bring the values of the first to bear on the second.

Proximity is the key to the mechanism whereby the nature of what is produced can satisfy the needs of the users. The network of social checks which causes production to respond to needs rather than create them, evolves only if social values have priority over economic ones.[1] The feedback which production receives from consumers is brought to bear through neighbours rather than through legislation, which must intervene in the public interest once proximity no longer exists.

An example of physical organization on the *national level* is provided by the petroleum industry on the coast of the Andean region. Mining was initiated with equipment owned by multinational corporations and local labour. The crude oil was exported and used in the manufacture of petroleum-based products. The prices paid for the crude oil were below its actual value on the world market as a result of the pressure which could be created in the mining operations. The goods which were manufactured and sold back, were often those which a developed country needs, for example, plastic telephones. It was through this economically motivated transfer of technology that the character of development was established. The effects of widespread distribution of the telephone might be better understood as another version of a transfer of tin-roof technology, the impact of which touches the most basic social customs.

Questions

1. How did the introduction of the oil industry cause a loss of proximity between living and working environments?
2. How does physical organization affect the development of a country?

Discussion: suggested responses

1. The labourers in the oil industry came from rural areas to work in the cities. While they earned more than they would have farming their land, they were no longer making a long-term investment in their own future. Whereas the control of a local workshop is in the hands of a person who lives in the community in which he produces his goods, centralized production operates according to the profit motive unchecked by local needs. The local manager must protect his personal and business identity by providing goods to the com-

1. Lewis Mumford, *Art and Technics,* New York, Columbia University Press, 1952.

munity which evaluates, uses and ultimately controls his socio-economic position. The corporate manager, on the other hand, has no direct way of measuring or understanding the ramifications of his production. Centralized production removes the personal intermediary between supply and demand. The mechanism of remote authority, remote production and distribution, serves to separate the decision-making from the values of the consuming communities. For this reason, products generated purely by the profit motive become substituted for products which served to reinforce traditional methods of production, and the related activities and life-style. Both the plastic telephone and the tin roof are examples of this.

2. By producing goods which support industries rather than the traditions of the consumers, a particular stalemate in national development occurs. When the oil along the coast of the Andean region runs out, the labourers will be forced to return to the land for their livelihood. The problem is that their land will have been left fallow for the years in which they worked in the industry. This land has taken many hundreds of years to cultivate and keep fertile.

After only a few years of neglect, it can no longer produce. What in the short term seems to create wealth as measured by a developed country, in the long run creates a kind of poverty: a particular kind of poverty which exists in the midst of a loss of traditional knowledge and social customs. Whereas the traditional decentralized workshop exists in a continuum of national development, centralized corporate production stems the slow tide and diverts its catch into foreign hands.

When a person who has grown up in a community decides to build a house for his own family, he contacts the neighbours and tells them that he intends to build and that they are invited to help him. For the next weekends, until the house is finished, the neighbours will be there. In turn, the next time anyone who has grown up in the community wants a house for himself, he will invite the first family to help. They would require extremely good justification not to take part. In this way, mutual responsibility is guaranteed. Thanks to proximity there is a system of social controls which creates the incentive to participate in serving the common good.

This proximity has an effect on the transmission of knowledge and experience as well. The person who grows up in the community knows how to build a mud-brick house, he knows how to farm, and he knows how to produce all those things which the community produces. This is the result of the proximity of the working and living places. Learning how these things are done is coincidental.

Technology, education and physical organization are linked systems. A second example comes from a brief comparison between two different types of physical organization, one which grew from a trial-and-error process, over several hundred years, and one which represents modern theory. During the process of simplifying social relationships and economic functions, so that they may be understood by students, planning education has tended to categorize systems.[1] One significant result of this practice is the creation of zoning concepts. When these concepts are put into practice, the benefits which occurred from overlapping functions are lost.

> Cities are an immense laboratory of trial and error, failure and success, in city building and city design. This is the laboratory in which planning should have been learning and forming and testing its theories. Instead, the practitioners and teachers of this discipline have ignored the study of success and failure in real life, have been incurious about the reasons for unexpected success, and are guided instead by tuberculosis sanatoria, fairs, and imaginary dream cities, from anything but cities themselves.[2]

The simple organization of a repair shop beneath a dwelling place, a market place in the public square, a bar or meeting-place on the street between two dwellings, or the close proximity of working and living activities, served to educate individuals about the technology related to their lives. When the economic activities of a neighbourhood were integrated with the living places, their requirements not only protected and supported, but also defined and limited, one another. The scale and image of an industry could not exceed or dominate that of housing, because residents place certain requirements on the character and quality of their home environment.[3] The increased activity in the street, which was created by workshops and commercial activity, made it more active during the day and therefore a more interesting place to be.[4] The evening activities in the homes made the streets safer when workshops and commercial establishments were closed.

In contrast to this 'ecosystem', modern cities and suburbs are zoned out of their functional interdependence. Suburbs are probably the most striking example. Zoning, in this context, requires individuals to employ cars to reach any other function. Goods and services are only available from some remote district designated for commercial development. Residents are not close to their neighbours while at home or while on the way to work. They cannot spend their days within the neighbourhood because their place of work is in some other zone, and they are not able to observe the kind of work their neighbours do because these functions are further separated according to type.

1. *The Athens Charter.* Conclusions of the International Conference of Experts of the Conservation of Artistic and Historical Monuments, Athens, 21–30 Oct., 1931.
2. Jane Jacobs, *The Death and Life of Great American Cities,* New York, Vintage Books, 1961.
3. Ibid.
4. Ibid.

Questions

1. In this context, from where do we derive knowledge about what is a quality product and who produces it?
2. What is the effect of this separation of functions?

Discussion: suggested responses

1. In a very broad sense, separating functions and, in that sense, separating people is a means for the economic incentive to maintain its control over the population. The separation of functions, and the implicit result of separating different vocations, has a self-fulfilling nature. As we argued in the case of the substitution of a tin roof for a tile roof, an addiction for high technology solutions develops out of a weakness in our own capacities, which lie unexercised during a situation of dependency. This phenomenon certainly exists in developed countries. A more alarming example of this is revealed by close inspection of the source of educational material for the evolution of our advanced technology. The most sophisticated research takes place in the laboratories of the corporations which develop the materials. In some respects, education is no more than a training programme for the corporations which in fact determine the course of technological evolution.

2. The destiny which we are alluding to, and the overlapping of functions which we have spoken of, solve this problem in two ways. First, they place production and its evaluation in proximity, a situation which, as we have discussed, allows production to be geared to values of usefulness. Secondly, and this is in some ways a more subtle phenomenon, a creative and re-associative process can begin again. In other words both producers and consumers can begin to see the alternatives to their products in the combination of other products, and the benefits which users derive from them. At the present time it is difficult to imagine an alternative to any one product, especially for the manufacturer, because the possibility of comparing and discussing is limited by functional separation.

STYLE AND IDENTITY

This example conceives the history of the adaptation of the Spanish colonial church to the pre-Columbian traditional religious customs. The intention of the New World builders was clearly to create a duplicate of the mother church in the region. The labour for construction was provided primarily by local people, who worked the materials with their own traditional skills and infused their own convictions into its appearance. Most churches in the region were planned with the processional nave characteristic of the Christian church and its liturgy. The indigenous people were accustomed to a completely different ceremony in which they gathered in large groups outside, around and on top of large earth or stone structures.

Stone carvings, Santa Cruz church, July [*Photo:* A. Alva].

The decoration of these structures varied with the region but reflected pagan, animal and agricultural characters inspired by spiritual values.

As the church was constructed, the plan and façade were transformed to represent the essential customs of the local people. The original Spanish plan called for one main entrance door, with the ceremony taking place inside in a hierarchical and solemn arrangement. But the local people would not use the inside of the church where the roof separated the ceremony from the sky, and the congregation was obliged to limit their participation to sitting or standing in rows. Instead, they gathered outside in the half-enclosed space created by the nave and the transept. The side portal, which gave access to the church from this space, was gradually transformed into an elaborate stage set for the performance of the adopted Christian rites.

The process by which the reorientation of emphasis was achieved is particularly important. It demonstrates the significance of individual attention and personal responsibility for the integration of the two strands of religious tradition.

The period in which the Spanish church was transposed to the region was considered architecturally as 'Baroque' in Spain. In this context, the façade would have required elaborate carvings and expressive ornamentation. The craftsmen employed to do this work had only a short time earlier been carving the elaborate and expressive characters of the region's fauna on their structures, as well as intricate foliage patterns depicting their environment. It comes as no surprise then, that the intended Spanish Baroque ornamentation of the church façade was in fact composed of significant local motifs.

Andean culture is sometimes referred to as 'archaic' and inflexible because of a tendency continually to reproduce traditional stylistic characteristics in arts and craft. In fact, people have a real but fragile capacity continually to reintegrate themselves with the new, a capacity which developed out of their familiarity with the technology.

Questions

1. How does responsibility for technology relate to the development of style?
2. Is the variation in regional materials significant for the variation of regional styles?

Discussion: suggested responses

1. This example of the relationship between technology and stylistic manifestation has to be understood in the context of the ideas which we have already mentioned. Although the people of the village where these churches were built might have kept their preferences for their traditional methods of working, they would surely not have been able to realize them in visual terms if they themselves had not been responsible for the constructions. Not only could they now recognize aspects of symbols they were familiar with, but they could sense involvement in a new style which both changed and preserved their culture. It is unrealistic to think that any culture can stand still nor is it desirable that it do so. It is important, however, to be able to understand how the imposition of a change can be integrated into the dynamic of images, references, and identity.

2. The transfer of technology in which people cannot participate must necessarily be detrimental to style. When transferred technology makes concrete and tin available to an entire country or even a large area, spanning different regions in which the local materials vary, the building style associated with that variation disappears. When the only materials available for construction are those on the site, the character of construction reflects their tolerances. In areas where stone is available, the style is different from areas in which both stone and wood can be used. Structural shapes, characteristic of each material, create an organization and profile with which people can establish an identity. That identity helps them to communicate with neighbours from other areas. It humanizes the landscape in the same way that understanding the characteristic of a material humanizes the elements of the physical environment.

When construction no longer reflects this variation, but rather reflects the homogenous image of mass-manufactured materials evenly distributed over the countryside, the humanizing identity is lost.

The concluding illustration is based on a comparison between style, identity and technology in the Andean region and those of an industrialized economy. The relationship can be discussed as having three components: (a) an individual's contact with materials and processes of production, in the Andean region, familiarity with construction techniques, in the case of the Spanish colonial church, enabled the local community to influence decisions about its construction; (b) the regional variation of available building supplies; the regional variation of materials made another level of differentiation, in which groups of communities were collected under one type of image, while other regions and their communities associated themselves with a different one; and (c) proximity, as a means by which social values influence decisions about the built environment; the workshops and stores were compelled to respect the demands of the inhabitants for a residential environment, with its characteristic scale and image.

In an industrialized country, these three components are also at work, producing another relationship between technology and style. As we have discussed earlier, improved technology has tended to put mechanisms which operate like 'black boxes' into all aspects of daily life. Whereas in an agricultural society each person is responsible for many aspects of his consumption, in an industrial setting, mass-manufactured products are shipped into every type of region to every type of community. Finally, the various functions of the economy are separated so that the character of each can develop without the limitations imposed by the values of the others.

Questions

1. How do distribution of materials and loss of density or proximity combine to influence style?
2. How does contact with materials and processes of production influence our ability to create a social/human imagery for our style?

Discussion: suggested responses

1. In place of an image derived from regional variation of materials, we have an image based on technology and economics. We have housing, institutional and industrial prototypes. Whereas these 'types' existed before, and were just as much related to economic and technological developments, the individual had an opportunity to feel responsible for them, to understand and modify them. In addition, each type responded to the demands made on it by the residential and living context. There was a social imagery.

Now we have the phenomenon of massive industry, with its blank walls, isolated in an industrial park where the only considerations are the economic ones. We have vast shopping centres, conglomerations and housing projects, each with its asphalt roofing system, its extruded-aluminium panelled ceilings, wall-to-wall carpets, fluorescent lights, and an ocean of black-top for our automobiles. We can find these images in New York and London, Paris and Stockholm.

There is no longer any direct way for a community to influence the nature of institutional or industrial building technology, except through graffiti. The habit and custom of modifying the technology of the domestic environment is surely being threatened by its inflexibility.

2. In fact, the inhabitant has developed a passive position which is recognizable in the residential environment.

At least one generation of users has become accustomed to concrete, aluminium, and tar, materials which are difficult to modify as living situations change. This generation has not observed the production of these materials, nor does it need to handle and become familiar with the characteristics of windows, taps and ovens. The propensity to create changes which satisfy personal requirements, is not encouraged by the nature of the physical environment. Both the social and physical channels for participation and interpretation are blocked. These carried with them, as we saw in the case of Challapampa and the Spanish colonial church, an ability to bring tradition into technology. The loss of this ability locks tradition out of technology.

CONCLUSION

In the first part of this study of each of the preceding pairs of cases we attempted to pin-point fundamental aspects of the relationship between tradition and technology. We tried to show that a close association between the individual and the technology he uses promotes personal commitment to the social and physical environment and its traditions.

In all examples we found a common thread. It is the recurring theme of the 'bond', referred to at the beginning, which we can now identify with greater precision and illustrate with a broad range of examples. This bond is the contact between the individual, whether he is a craftsman, a user or an observer, and the characteristics of the materials, the processes of production and the situation for which technology is being developed.

Its significance lies in the degree of involvement in the relationship which binds people to their physical, man-made environment.

We saw how the loosening of the bond by the development of a remote position and the loss of first-hand knowledge limits the understanding an individual can put to use in his own surroundings. The example of the tin roof referred to a transfer of technology which inhibits people from repairing their own houses; the example of detrimental planning programmes showed the lack of understanding which occurs as a result of principles that are not developed in contact with the communities for which they are intended; the example of the expert seismologist who categorizes adobe construction as 'weak' also illustrated the problem of relying on education which has developed its values outside the realm of actual experience.

In all these cases the significant factor is the knowledge an individual develops from his own experience. The transfer of knowledge provides the most realistic opportunity for improving his understanding. In fact, the knowledge which is transferred through experience is most likely to provide individuals with the ability to control their environment and understand the technology behind the situation they find themselves in.

As we have seen from our comparisons, different types of experience are available within each context. In other words, what constitutes the most basic first-hand knowledge is at one level in one context and at quite another in a different context. Whereas an Andean villager still has the opportunity to learn at first hand, the average person in the industrialized world receives his basic knowledge from observing the mechanisms and materials of advanced technology. Again, first-hand knowledge can be readily absorbed at one level in one country and at another in a different country. In the Andean region, the most powerful form of education is daily involvement in the production of what is consumed. In the industrialized economy, exposure to technology which is not produced by the individual is basic to the system of education.

By understanding the level at which a culture can absorb knowledge, it may be possible to direct a transfer to just the point in the 'technology chain' where it will have the most profound effect. This effect could serve to strengthen the bond, and is therefore to be preferred to the pursuit of so-called 'appropriate' alternatives as defined in the introduction.

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Joined the Royal West of England Academy School of Architecture, in the United Kingdom, in 1961, to train as an architect. Being of a practical mind, rather than a designer, became more interested in traditional architecture and how buildings fitted together; prepared a thesis on a scheme for the conservation and rehabilitation of the Theatre Royal in Bristol. Appointed architect and project leader of the Unesco Hanuman Dhoka Restoration Project. Later co-ordinator for the programme for the Safeguarding the Cultural Heritage of the Kathmandu Valley. Still based in Nepal, he now works as a freelance consultant in building conservation and repair. Also involved in the design and construction of groups of traditional buildings for jungle lodges in southern India and Sri Lanka.

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