UP TO THE WAIST IN MUD!

The assessment and application of earth-derivative architecture in rural Bangladesh

by

Khondkar Iftekhar Ahmed

Bachelor of Architecture (Hons.)
Indian Institute of Technology
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Signature of the Author ______________________________
Khondkar Iftekhar Ahmed
Department of Architecture
May 15, 1991

Certified by ______________________________
Prof. Ronald Lewcock
Professor of Architecture and
Aga Khan Professor of Design for Islamic Societies

Accepted by ______________________________
Prof. Julian Beinart
Chairman of Departmental Commitee for
Graduate Students

TO

Abbu, Ammu
and Boppa, Chotapa, Una

and Tatjana

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Submitted to the Department of Architecture on May 15, 1991 in partial fulfillment of the requirements of the Degree of Master of Science in Architecture Studies.

ABSTRACT

This thesis is about architecture that uses earth as the prime building material in the context of rural Bangladesh. In extreme environmental conditions of annual floods, rain and atmospheric humidity, the use of earth, the most readily available building material, faces serious constraints. Yet examples of earthen architecture abound there. Other parts of the world endowed with similar climatic and socio-economic conditions also yield interesting examples of such architecture. The advent of imported, industrial building products has disrupted the long-standing indigenous building traditions. New social, cultural, economic and environmental conditions necessitate the upgrading of local building techniques. In recent years, much work and research has been conducted to develop improved techniques of building with earth. Not all the improvised methods can be applied in the context of rural Bangladesh, yet some do indicate potentials for application. Methods of evaluating such applicable techniques, and of formulating design guidelines and principles for using them in rural Bangladesh form the main subject matter of the thesis.

Thesis Supervisor: Ronald Lewcock
Title: Professor of Architecture and Aga Khan Professor of Design for Islamic Societies.

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CHAPTER I

"I am awed by their imagination too, and what their hands have done. I look down at my clean fingernails and wish for mud." (1)

CHAPTER I. INTRODUCTION

This thesis is about earth and water. And bamboo. Water flows through the delta in Bangladesh depositing annual endowments of alluvial earth. The life of the rural inhabitant is intricately linked with the water and soil of the land. The gift of the rivers is used ingeniously to build splendid buildings. But the annual riverine floods, the incessant monsoons and the insidious humid air gnaw away at these buildings - as if the generous donors demand the return of their gifts. A continuous battle is waged against the adverse elements to preserve the earthen buildings, the same buildings which protect the rural inhabitant from those elements.

While this fascinating interplay between nature and human beings is being enacted, contenders to indigenous building materials, in the form of imported and industrial products have created images of modernity and glamour, as well as permanence. Drastic change is disrupting the continuity of tradition. Is tradition destined to perish this way? Surely tradition cannot be encapsuled and frozen in time. But the alternative is certainly not complete defacement! Memory must persist in a new form: the perpetuation of the natural evolution of culture entails reproduction from within the culture, not from without.

This, then, is the setting which this thesis addresses. It attempts to recognize the intrinsic value of the great cultural traditions of indigenous architecture, and at the same time realizes some of its drawbacks in the context of the present age. While a reappraisal of the building traditions is vital, it should go hand in hand with improvement techniques which are tuned to new demands.

The title of my thesis certainly arouses the curiosity of the reader. Therefore, I will examine the contents of the title, which will provide illumination on its origin, scope and intent.

A large majority of the inhabitants of Bangladesh have to adapt to a lifestyle dictated by the annual floods. They literally have to wade through muddy water which often is up to the waist. The same earth and water also provide a freely available building material. It is this material - earth - which this thesis essentially deals with.

There are two main themes that I have attempted to assess. One is the existing traditions of indigenous building techniques, with the main emphasis on earthen architecture. The other is the innovative improvement techniques that have been developed in recent years. Based on the assessment, a potential marriage between these two themes have been proposed, which is what I have termed as "application".

Why rural Bangladesh? Bangladesh is a rural country, with nearly 80% of the population living in rural areas. There is only one primate city, and a few smaller ones; the rest of the country is predominantly agricultural. Yet the lion's share of the attention of the architectural profession is directed towards the urban built environment. At this point there is a need to re-direct this attention towards the rural sector, in order to preserve the cultural tradition of the indigenous architecture.

What is "earth-derivative architecture"? I have coined this term due to the absence of an existing appropriate term which would render justice to my proposed marriage between tradition and innovation. "Mud architecture", to some, consists of pejorative connotations. "Adobe architecture" is limited in the real sense of the word, if not in general perception of the term. "Earth architecture" has been defined by DAI Nainci at the International Symposium on Earth Architecture as "dwellings built with earth or with aggregate too" (1). This term is the closest in meaning to the architecture pertaining to this thesis. However, in many instances I have dealt with buildings which utilize bamboo as the prime building material in conjunction with earth. I am not certain if such architecture can be defined as "earth architecture". Nevertheless, earth construction to be lightweight enough to avoid high thermal capacities, needs a reinforcing framework, which bamboo or wattle and daub provide. It seems reasonable to add "or additional reinforcing" to DAI Nainci´s definition above. When most of the architecture that this thesis addresses have been derived from earth, or use earth as one of the building materials, if not the main one, the term "earth-derivative architecture" seems an appropriate one.

This thesis has five main parts. In the second chapter, I have introduced the context and the existing traditions of earthen architecture there. In the third chapter, the relationship between climate and architecture, which has often been emphasized, is investigated. A study of the indigenous earthen architecture in other similar contexts is an significant part of this chapter, to draw parallels and distinctions between those contexts and Bangladesh. This is intended to provide a direction for the viability and improvement potential of earthen architecture in Bangladesh, by demonstrating the prevalence and adaptation of earthen architecture in similar, yet different contexts. I consider the fourth chapter as containing some of the most important aspects of the thesis; this is where I have assessed the innovative techniques that have been developed for the improvement of traditional earthen architecture. The fifth chapter brings the work to a general conclusion, as it attempts to provide directions for improvement based on the work and research done by others, and also in relation to the contents of the rest of the thesis. As the thesis was nearing completion, I felt the need for a final conclusion which would draw some of the salient features of the thesis, specially my strategies for improvement, and the technical aspects of the proposed improvement of earth architecture and other indigenous architecture of Bangladesh. I have attempted to do so in the sixth chapter.

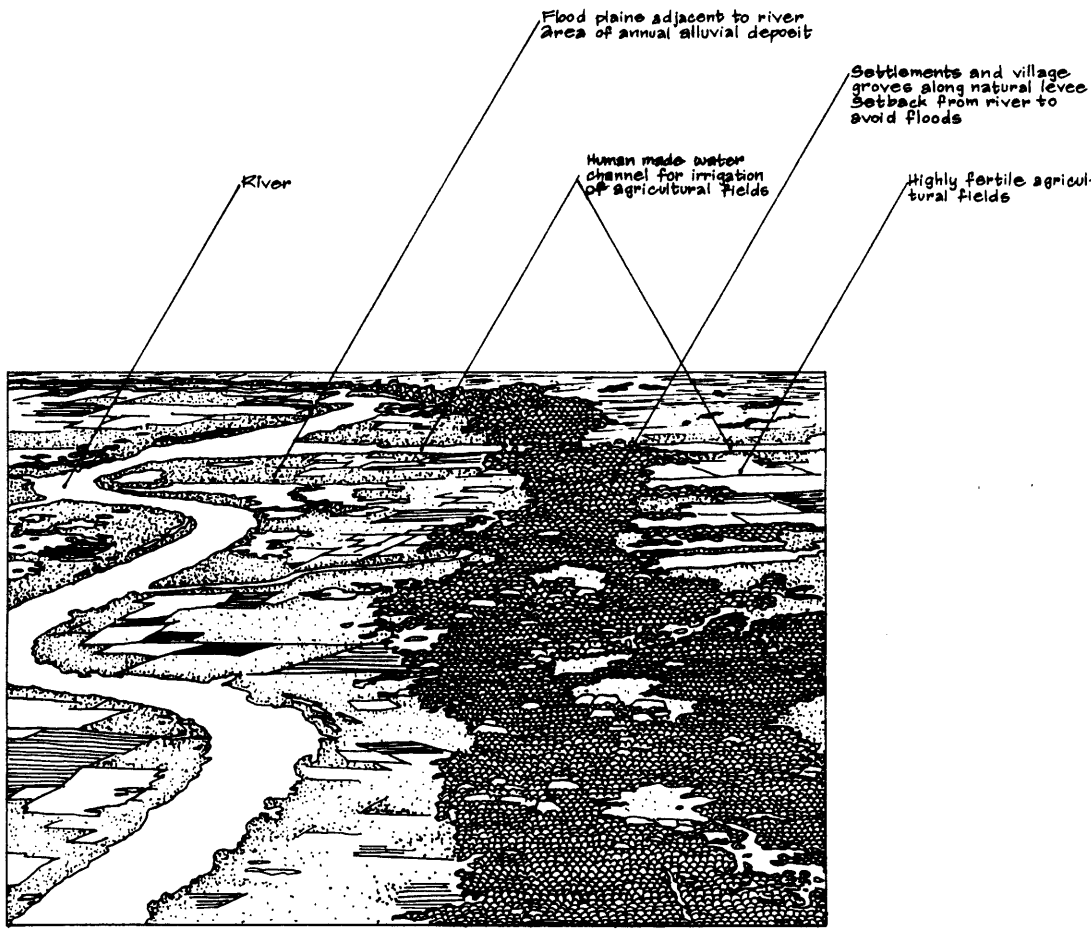
Having said all this, one final note must be added. The topic of earthen architecture is quite wide in scope. It is believed that "Some 40 per cent of the world´s built structures are made of earth and house nearly 50 per cent of the world´s population" (2). I have attempted to narrow down this broad topic by adhering strictly to the context. Important pioneers, the prodigious work of folk builders, cross-cultural analyses and all the various innovative techniques of earthen architecture have been sieved to yield those that have a direct bearing on the theme of the thesis. If I have not rendered justice, by not paying extensive homage to pioneers, builders and traditions of world earthen architecture, it has been done with the hope that they exist in spirit, if not in material form, as inspiration for this thesis.

------------------------- NOTES -----------------------------

1. Virginia Gray, Alan Macrae and Wayne McCall, Mud, Space and Spirit, with a Foreword by Noel Young (Capra Press, Santa Barbara, Calif., 1976), p.10.

2. Barbro M. Ek, "Adobe 90," Mimar 38 (March 1991): 13.

CHAPTER II



"See, mother, it is almost dark before the day is over, and there are no travellers yonder on the village road.

The shepherd boy has gone home early from the pasture, and the men have left their fields to sit on mats under the eaves of their huts, watching the scowling clouds." (1)

CHAPTER II. CONTEXT : CULTURE, CLIMATE AND EARTH ARCHITECTURE

II.1. INTRODUCTION TO BANGLADESH:

Physical nature: The country of Bangladesh is predominantly comprised of flat, alluvial land and is generally described as a delta. The delta is formed by three large rivers - the Ganges or Padma, the Brahmaputra and the Meghna - and their numerous tributaries. In fact the lower southern part of the country is mostly composed of islands formed by the river systems! Also described as flood plains, the land is mostly flat, except for the lower south eastern part, which is somewhat hilly.

Climate: The climate of Bangladesh is hot-humid and tropical, and the average temperature is between 75 and 80 degrees Fahrenheit (24.4 and 26.7 degrees Centigrade). The rainfall varies from 47.25 inches (120 cm) in the western part to nearly 100 inches (250 cm.) in the south and 225 inches (570 cm.) in the north eastern part. Most of this heavy rainfall (almost 80 %) is due to the annual monsoon rains, during the months of June to October. Being preceded by a short hot and dry spell, the monsoon season is also followed by a brief cool and dry season. The humidity is

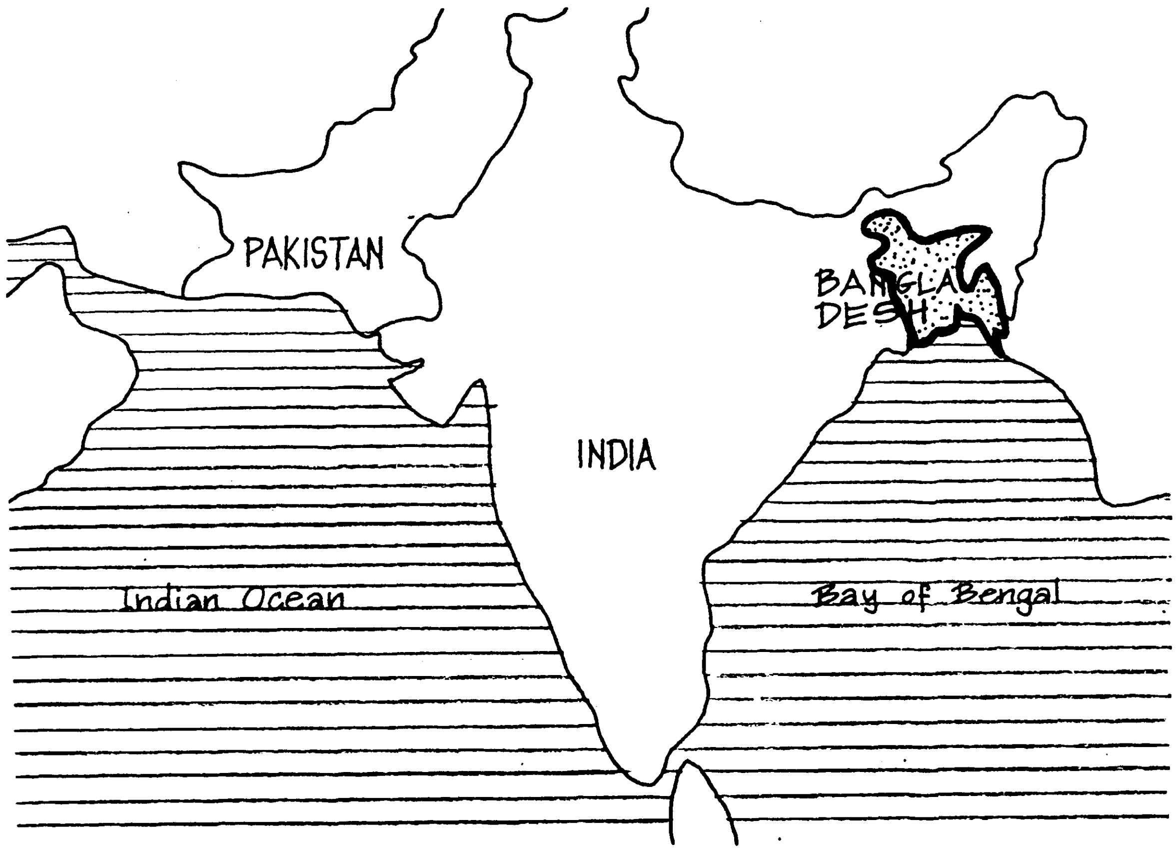


Fig. II.1. Location map of Bangladesh.

high most of the year and in some areas, at times, the relative humidity is more than 98 %.

Environmental conditions: In Bangladesh major parts of the country are flood prone, and are flooded annually due to overtopping of the river banks in most of the affected areas. Impounding of rainwater is also a cause of floods, especially in low-lying areas. The north western part and the hilly areas are less flood prone. The coastal areas in the south are subject to cyclones, and at times, tidal surges. In many of these areas the wind speed rises up to 100 miles per hour (160 km./hour). Often, such adverse climatic conditions result in disasters which involve loss of human lives, property, livestock and crops.

Socio-cultural conditions: Bangladesh is predominantly an agricultural society. Agriculture accounts for about 50 % of GDP, 75 % of employment and over 80 % of export earnings. Being agricultural, most of the country is rural with about 85 % of the population living in rural areas. There are a few urban centers, notable among them the capital city Dhaka, which is growing rapidly. There is limited industrial development, which is mostly concentrated in the urban areas. However, the climatic conditions and geographic location are favorable for the agricultural and rural character of the country.

There is a severe shortage of institutional and social amenities in most of rural areas. In the southern deltaic and coastal areas, the indigenous housing is subject to adverse climatic conditions, and is often damaged by natural disasters. Many of these areas do not have adequate transportation links. Bangladesh has been characterized as being one of the poorest countries of the world, with severe shortages of resources, foreign currency and imported products.

The area of Bangladesh is about 56,000 square miles (144,000 sq. km) and has a population of 110 million people (that is, about seven times larger than the State of Massachusetts, U.S.A., which has an area of 8,257 square miles and population of around 6 million) (2). The country is one of the most densely populated areas of the world, with an average density of nearly 2000 people per square mile (approx. 850/sq.km). Being such a highly populated country, available land and resources are in short supply. However, there is a large supply of manpower, and most of the agriculture, industries, transportation and building construction is labor-intensive.

The prevalent religion is Islam, with 86.6 % of the population Muslims, 12.1 % Hindus, 0.6 % Buddhists, 0.3 % Christians and 0.4% others. (3)

II.2. THE VERNACULAR HOUSE AND CHANGE:

The basic house form in rural Bangladesh is longitudinal and rectangular in shape. Frequently the houses and ancillary buildings, such as granaries, stables and outhouses, are clustered around open courtyards. They are usually single storied and sometimes double storied. In marshy areas the houses are often raised on stilts, but this is less common than raising the land by forming artificial earthen mounds from earth obtained from the excavation of canals and ponds. The houses are built in clusters on these mounds and are protected from floods. In general, the basic house form and settlement pattern is similar throughout most parts of Bangladesh, which is mainly the result of adaptation to the macroclimate, but there are regional variations in terms of materials and construction techniques, and in some cases, also in terms of form and layout. These variations are adaptations to the microclimate and physiography of the land, as well as to the availability of building resources. (4)

The description of vernacular house form above is rather broad in nature. It is not within the scope of this thesis to deal extensively with that subject, rather the aim is to explore the use of earth in the construction of rural buildings in Bangladesh. I have undertaken a study in this regard based on the physiography of the land, which yields typologies of earthen buildings which comprise a substantial

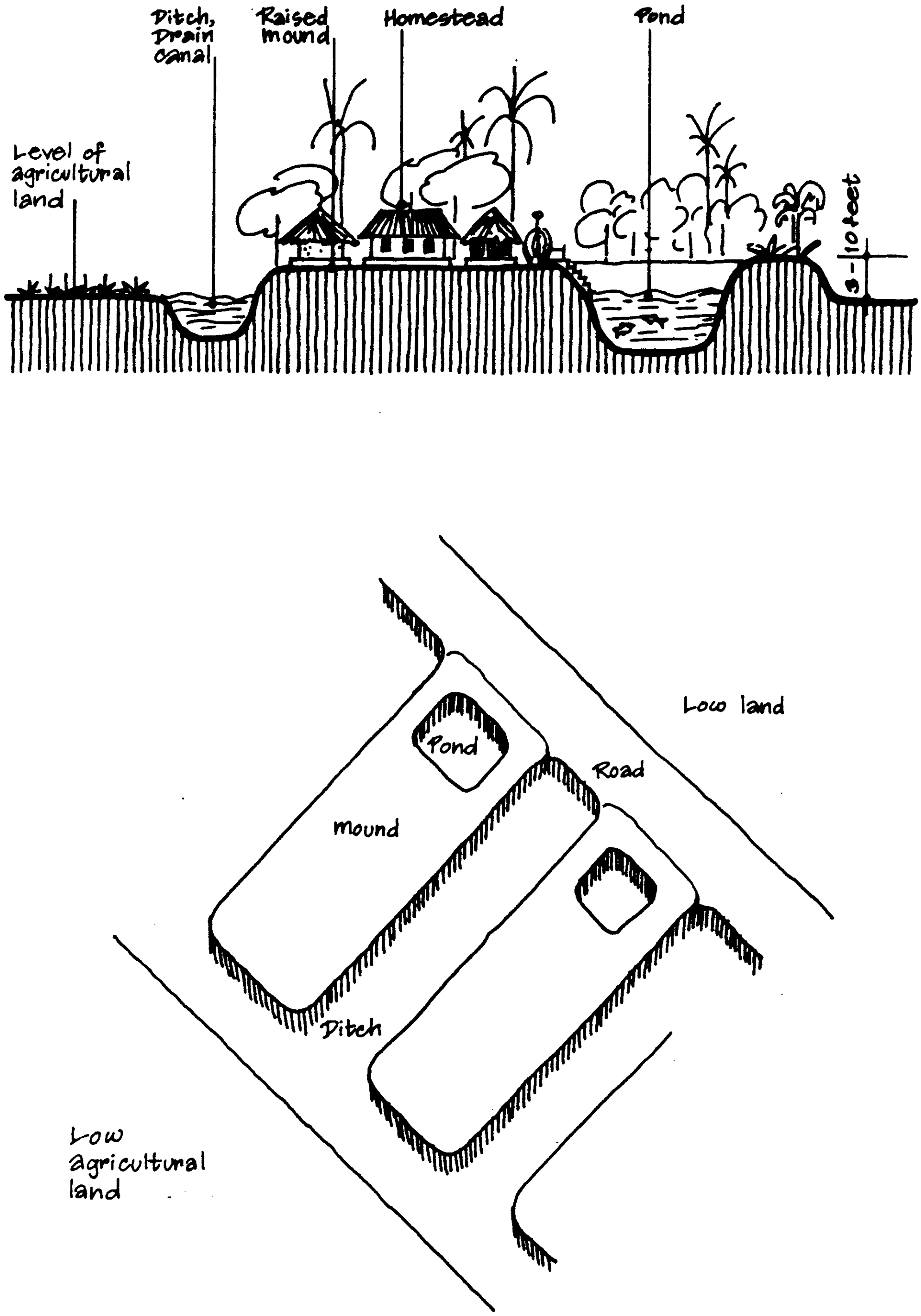


Fig. II.2. A typical settlement pattern in Bangladesh.

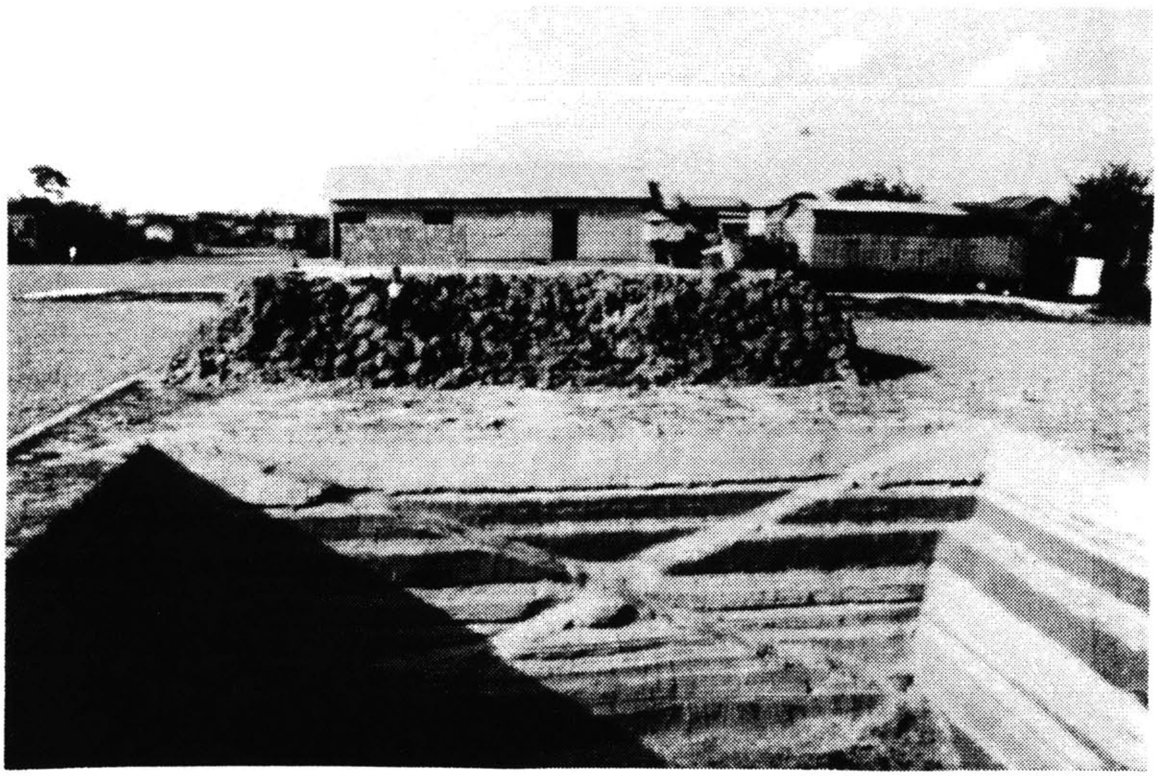


Fig. II.3. Digging ponds and canals, and then heaping up the excavated earth into mounds to build homesteads.

Fig. II.4. A typical homestead.

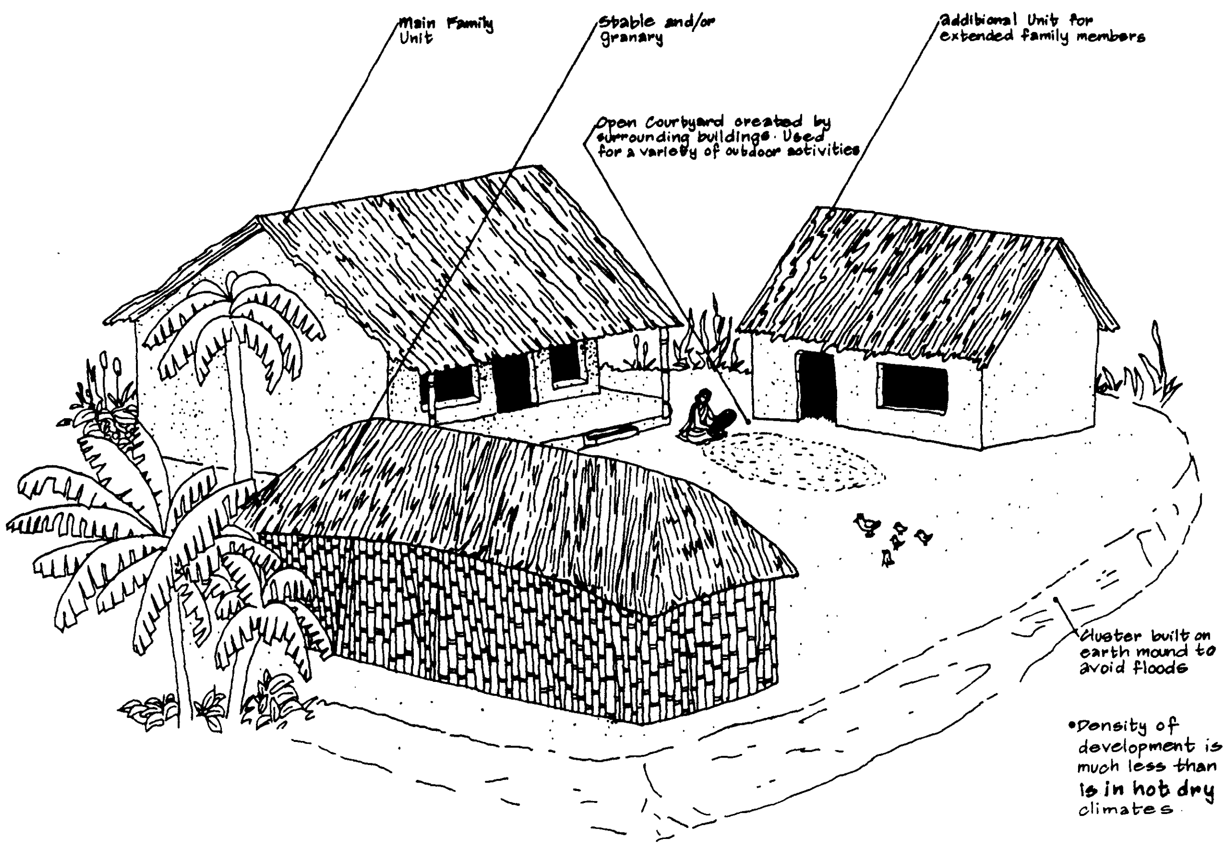


Fig. II.5. A typical homestead showing the salient features.

portion of the vernacular housing stock. In the past, such earthen buildings would have constituted the majority of traditional rural housing (and also some of the institutional buildings), but at present industrialized building products, mainly corrugated iron sheets (commonly known as "tin sheets"), are rapidly replacing the traditional building materials. Before I describe the existing earthen buildings based on the physiography of the land, I will discuss the advantages and disadvantages of the use of corrugated iron sheets (hereby referred to as C.I. sheets).

II.2.1. C.I. sheet as a building material:

C.I. sheets have been increasing in popularity since the late 1950s. They are generally imported, or flat steel sheets are imported and the corrugation is done in Bangladesh. They are basically galvanized steel sheets, which are corrugated later. C.I. sheets are used mostly for roofing and also for walls. I will describe the reasons for their popularity in both these forms.

a. C.I. sheet roofing: Originally indigenous rural buildings in Bangladesh had (and still have in many areas) roofs constructed of various types of thatch. These types of roofs required frequent maintenance in the rainy climate, and were thus perceived to be poor in quality. Most of the thatch roofed houses belonged to the poorer segments of the rural population. The more affluent constructed the roofs of stables, outhouses etc. out of thatch, while the roofs of dwelling units were in former times constructed of more durable fired clay tiles, and now are being constructed of C.I. sheets.

Before independence from British colonial rule, the roofing tile production was operated by a class of Hindu potters. After independence, due to the partition of India into Muslim Pakistan (with Bangladesh being East Pakistan at that time) and Hindu India, there followed a mass migration of Hindus from Bangladesh to neighboring India. Much of the art of fired clay tile production disappeared from Bangladesh at that time (5). Some examples of vernacular clay tiled roofs can still be found in the western part of the country, which borders India, where the art has managed to survive to some extent. It is in this juncture of time that the advent of C.I. sheet roofing took place and gained popularity.

While C.I. sheet roofing may be a symbol of permanence to the rural affluent, for most of the rural poor it is yet, to a large extent, an inaccessible building material in terms of costs. The resources required for the production of C.I. sheets are not available in Bangladesh, and therefore the C.I. sheets are imported, or the raw materials areimported and then the sheets are produced locally. This

Fig. II.6. C.I. sheet - symbol of permanence for the rural affluent and a resalable commodity for the poor.

particular case in Bangladesh has been discussed more generally by Spence and Cook:

> "But perhaps the most serious problem with corrugated iron sheets is that so many of the countries using them are without a steel industry, and either import the finished sheets or import flat steel sheet which is then pressed and galvanized locally. Thus, a high proportion of the cost of these sheets is in foreign exchange which these countries can frequently ill afford and consequently they will be either very expensive or unavailable." (6)

However, investment in a C.I. sheet roof for the poor means investment in a resalable commodity to be relied on in times of dire need. Thus, as it can be sometimes observed, poor people who cannot afford a house completely constructed of C.I. sheets, have houses with bamboo mats or earthen walls with C.I. sheet roofing.

Apart from their thermal disadvantage, which I will discuss below, C.I. sheet roofs are noisy during rainy periods, which are common in Bangladesh. The use of sound dampening layers or false ceilings may reduce the noise, but this would automatically increase costs of labor, construction and materials.

b. C.I. sheet walling: Following their introduction as a roofing material, C.I. sheets also began to be used for walls. Again, this was in the well-to-do sector of the rural population. After the partition of India, the local governments began to build some institutional buildings, such as schools, health clinics, post offices and administrative buildings in the rural areas. The only choice of a permanent local building material was fired brick, which proved to be too expensive in many cases. No local mode of roofing, perceived as suitable for these buildings, existed at that time. Thus, at that time buildings began to be built in the rural areas out of brick with C.I. sheet roofs or entirely of C.I. sheets. This institutional application soon influenced the domestic buildings of the rural affluent.

According to Hasan,

> "Corrugated G.I. sheet despite its thermal disadvantage, is socially preferred, because of its relative permanence, and its ´utility´ character." (7)

The thermal disadvantage of C.I. sheets is a serious problem, especially in a hot-humid climate like Bangladesh. They heat up very fast and also cool down fast. In fact, on hot summer days, they become so hot that it is dangerous to even touch them! Givoni has written about the thermal properties of C.I. sheets in terms of their absorptivity, emissivity and reflectivity:

> "a polished metal has a very low absorptivity and emissivity for both shortwave and longwave radiations. Therefore, while being a good reflector of radiation, it is a poor radiator and can hardly lose its own heat by radiative cooling." (8)

When a shiny C.I. sheet is installed, it reflects a portion of the short wave solar radiation, and allows the majority of the remaining radiation to pass through to the interior of the building. In this process the short wave radiation is converted to long wave radiation, and as the absorptivity of the C.I. sheet for long wave radiation is low, the interior of the building consequently becomes hot. The small portion of radiation absorbed cannot be emitted easily and therefore causes the sheet to heat up. If the sheet was white in color, then a much larger portion of the incident solar radiation would be reflected, and hence the interior would remain cooler. When C.I. sheets age and acquire layers of rust on their surface, they become darker in color and consequently reflect even less radiation than the shiny sheets, and absorb and emit more radiation. Thus, the interior of buildings of rusted corrugated sheets become extremely hot, and on warm days can be intolerable. Koenigsberger and Lynn have provided data which substantiate the adverse comparative thermal properties between new and shiny, and old and rusted C.I. sheets (9).

In humid areas the diurnal temperature variation is not great, and the high insulation value of thick earthen walls characteristic of hot-arid areas is not an important requirement. However, thin earthen walls provide the necessary balance between the exterior and interior temperatures, by adapting to the relatively low diurnal swing of temperature. C.I. sheets with their lack of insulative quality do not provide the necessary balance, and on hot days allow the interior to heat up rapidly, and on cold days also allow it to cool down rapidly.

The thermal disadvantage is a cause of severe discomfort for inhabitants of C.I. sheet buildings. As noted by Hugo Navarro about the use of C.I. sheets in Panama, which is a climatically similar region to Bangladesh,

> "problems like heat irradiated from tin roofs, rapid variations of temperature of approximately 10 degrees Fahrenheit or more produced by excessive humidity with the production of high condensation, affecting the population with colds and allergies which affect their physical conditions." (10)

It may be argued that the use of some form of insulating material along with C.I. sheets may improve their thermal quality. However, such a practice is absent in Bangladesh, and its application would entail the introduction of a new production and distribution system and training facilities. This would further increase the cost of construction; at present, only the rural affluent can afford C.I. sheet buildings and their improvement would further amplify the problem of the inaccessibility of the poor to such building systems.

C.I. sheets develop layers of rust on their surface when exposed to the rainy, wet climate of Bangladesh for a prolonged period. Preventing rust, or cleaning it off the surface requires expensive chemicals which are not available in most rural areas. Thus, C.I. sheet buildings are allowed to develop a rust-coated and tarnished appearance, which is neither appealing to the inhabitants nor physically clean. Some natural materials, like wood and brick, age in such a way that the weathered texture does not appear ephemeral, but C.I. sheets do not age well and by rusting appear to lose their initial shiny charm, which is usually associated with newness and value. These rusted sheets often have a demoralizing effect on their owners because of associations of poverty and cheapness.

There are several qualitative grades of C.I. sheets which are available. The lower quality sheets which are affordable to low-income groups corrode and develop rust quite rapidly. The better quality sheets are more durable and also more expensive. Thus the demoralizing effect is further ramified by the inability to afford the better quality sheets.

Two important conclusions can be drawn at this stage. These conclusions provide direction for improvement of rural Bangladeshi architecture. The conclusions are:

a. There is a need for the development of a suitable roofing material for rural Bangladesh. The production of fired clay roofing tiles should be revived if possible, because it utilizes the locally available material - earth, and also because its production generates employment. This, of course, entails a new initiative and may be difficult to realize. The production of fired clay tiles is an energy-intensive process, therefore availability of fuel has to be

Fig. II.7. Rusted and tarnished C.I. sheets can be demoralizing for the owners.

assessed along with its potential for generating a labor-intensive process. Alternatively, C.I. sheet roofs may be covered with thatch to protect from heat/cold and may even function as sound dampers. This practice may also effectively conceal the rusty and shabby surface of C.I. sheets. Some development in this direction has already begun in some places, and should be developed in a more systematic way to make it widely acceptable.

The original and indigenous roofing in Bangladesh consists of various forms of thatch. Much evidence of this practice is derived from Anthony King's account of early travellers' descriptions of the indigenous architecture of Bangladesh (11). Thatching is certainly a practice rooted in locally available resources and skills, and has been adapted to the climate. In spite of this rationale of its use, it presents several problems, the main one being that it is a system using perishable materials and hence requires frequent maintenance and replacement. Also in the tropical climate of Bangladesh, thatch is a nesting ground for harmful insects.

Improvement of thatching can be accomplished, making it suitable for use in dwelling units. However, this is not the place to dwell on the subject of roofing exhaustively, as I will discuss such possibilities for improvement in Chapter V. In any case, its use in ancillary buildings like outhouses, stables and granaries should be continued with.

Fig. II.8. The use of thatch to protect C.I. sheets of thatch to protect C.I. sheets is common in many areas.

Fig. II.9. Traditional thatched roofed buildings in Bangladesh.

the objective of devising methods for improving it. Thatching does provide an inexpensive and labor intensive alternative to the more expensive C.I sheet roofing, and research in this area has to be conducted to make thatching viable for more widespread use.

b. The popularity of C.I. sheets gained momentum following its introduction by its use in institutional buildings. Institutional buildings funded by public agencies and which attempt to apply a new concept in architecture often set examples for private agencies, and in this way the concept trickles down to be eventually used in domestic buildings (12). Resources made available institutionally or otherwise is an additional aid to the effective implementation of this notion. In the search for a suitable architecture for rural Bangladesh, this notion may be explored to introduce new building techniques, which are rooted in existing practices. The notion of change introduced by external agencies which originate from tradition may yield successful results.

II.3. PHYSIOGRAPHY AND CONSTRUCTION METHODS:

While the physiography of Bangladesh has many regional variations, it can be broadly categorized into three main areas. Here I will describe the indigenous or vernacular architecture in each of these areas; the emphasis will be on earthen architecture which constitutes the majority of the buildings. It will be evident that most of the discussion is centered around domestic architectural forms and not around institutional buildings. Bangladesh being an agrarian society, the architecture is mainly domestic, and other than religious buildings there is no evidence of any other institutional building type in rural areas before the advent of British colonial rule.

Based on physiography, the three different regions and their architecture is described below.

II.3.1. Pleistocene Uplands:

As is commonly known, land in deltas is formed through the gradual sedimentation of alluvial soil, deposited by flowing rivers. This is a long and slow process - where it may take many centuries for such land to be consolidated. Most of the land presently known as Bangladesh has been formed by this process. As the name "Pleistocene" suggests, this region has been formed at an earlier period than the other parts of the land. Consequently it is at a greater distance from the coast and is less prone to strong winds, cyclones and floods. It is also located on a higher elevation, with a gradual slope from north to south. Some parts of the north western part of the country and the area north of Dhaka has been characterized as the Pleistocene Uplands.

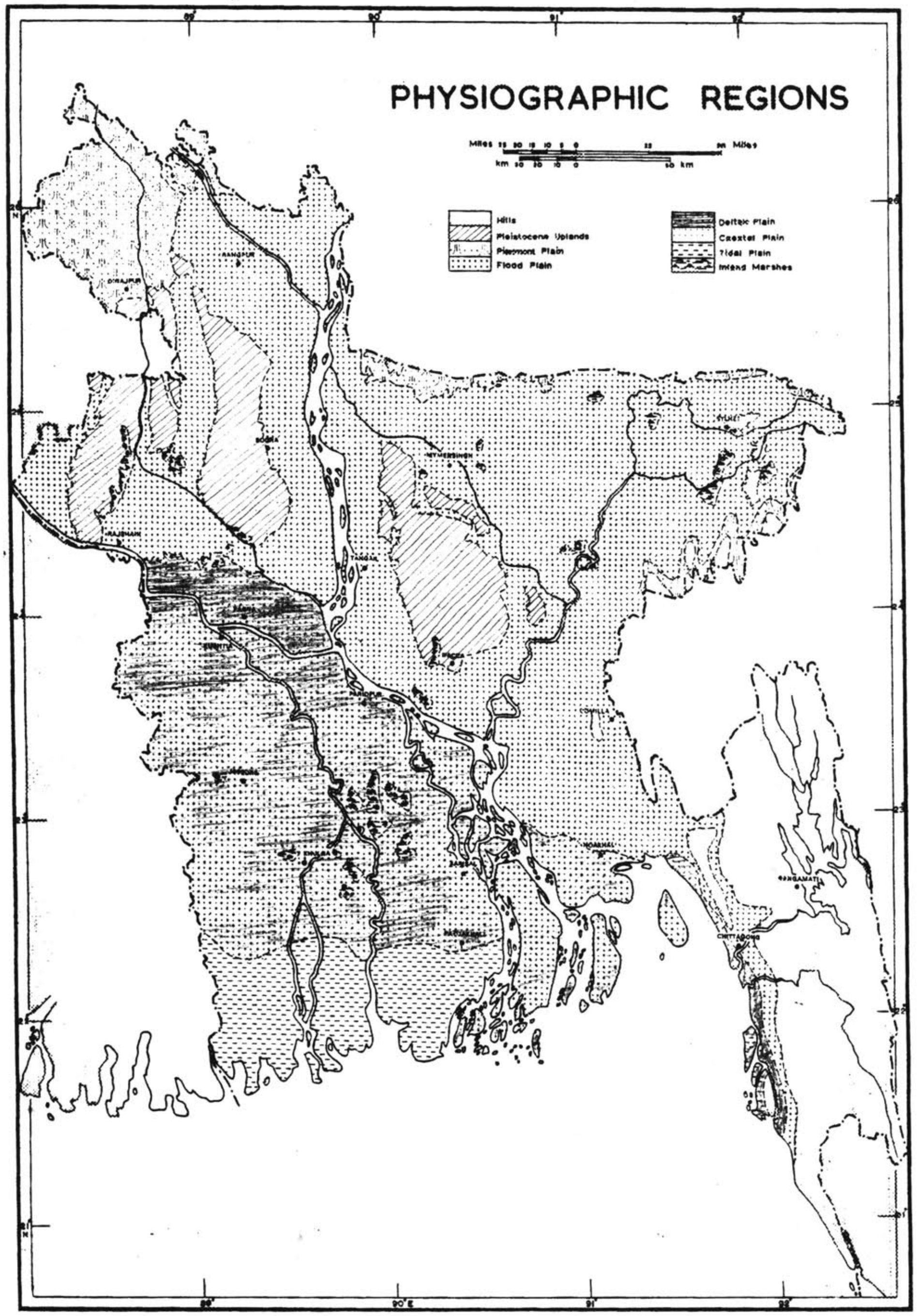


Fig. II.10. Map showing physiographic regions of Bangladesh.

There are mainly four types of earthen buildings in this region. Here I will provide descriptions of these main types, based on their methods of construction:

a. Layering technique: The majority of earthen buildings are built in the layering technique, which is similar to the pise technique (13). Examples of even two storied buildings constructed in the layering technique exist. Early descriptions of travellers confirm the prevalence of this technique. As documented by Captain Thomas Williamson in 1810,

> "The walls of permanent buildings were usually constructed of mud laid in strata of 18 - 20 inches in depth, each stratum being allowed to dry before the next was added. Walls were between 26 to 30 inches thick at the base, tapering to about three-quarters of this breadth at the top." (14)

In most cases, a mound of earth is shaped and then rammed to form a plinth, on top of which the walls are begun. No finish is applied on the rammed mound, except for a layer of mud slurry to achieve smoothness, and it is left bare to serve as the floor inside the building. In some places, foundation trenches are dug and the walls are erected from inside these trenches (15). Even in this type, the floor is of bare rammed earth on a raised plinth.

The raised plinth is a characteristic feature of most rural buildings in Bangladesh. It is common in almost all the physiographic regions. Anthony King, while tracing the roots of the British colonial bungalow back to indigenous

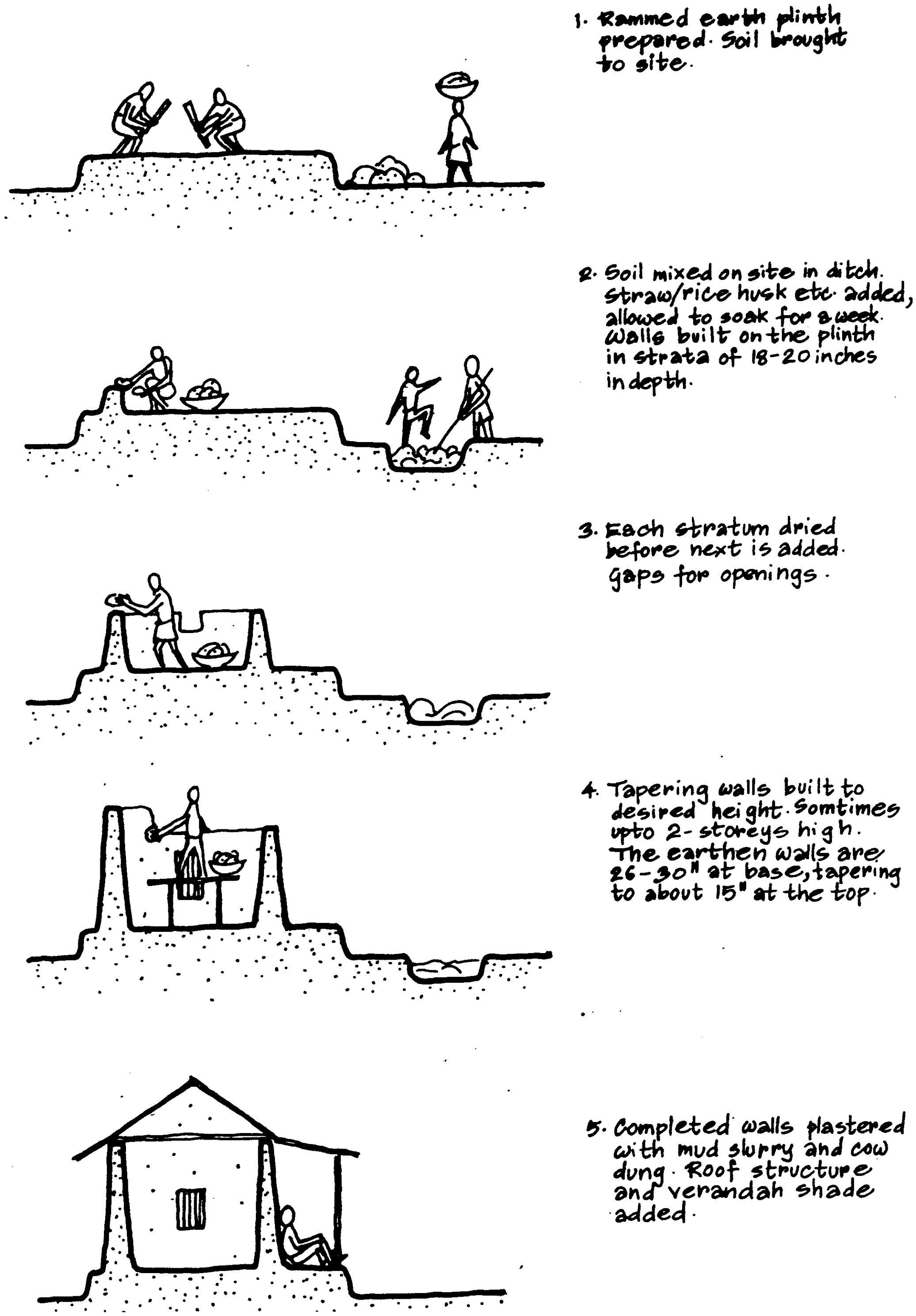


Fig. II.11. The layering technique for building earthen walls.

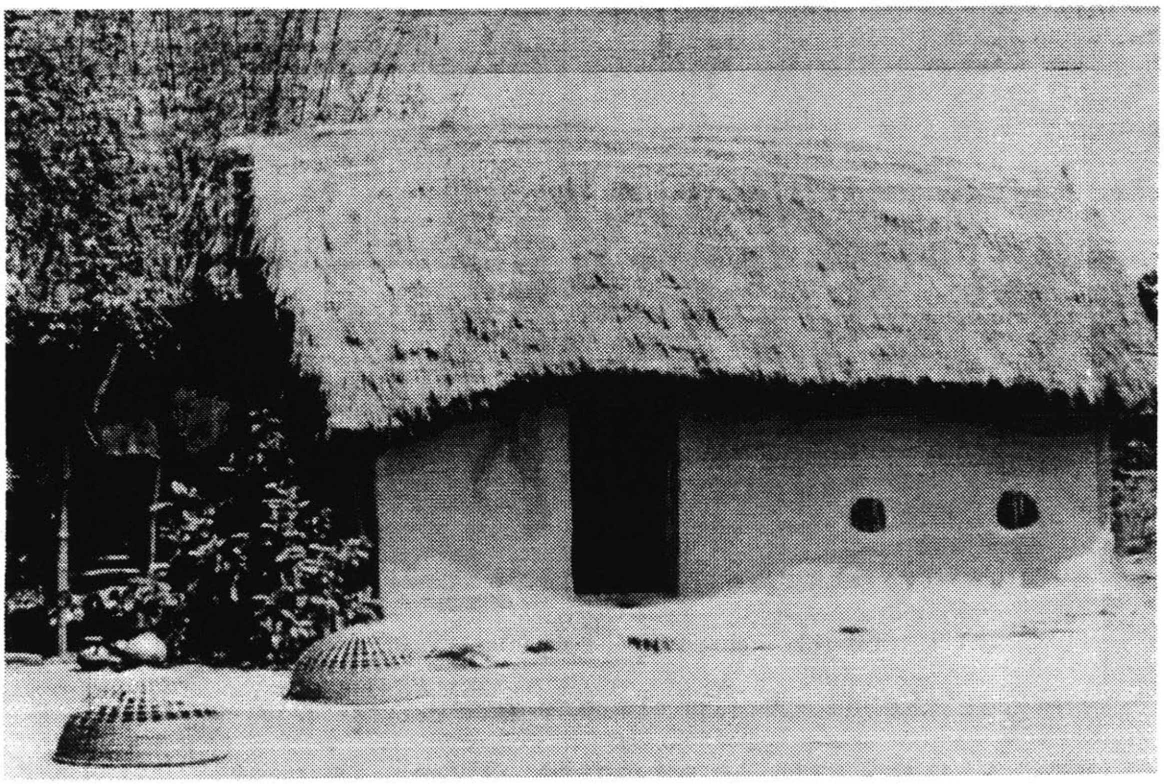


Fig. II.10. House built in the layering technique.

architecture of Bangladesh, has commented,

> "its free-standing and single storey structure, the plinth, the pitched, thatched roof and the verandah - are all characteristic features of the indigenous Bengal hut," (16)

The origin of the earthen plinth can be traced to the practice of digging irrigation canals and ponds, and using the earth from excavation to form artificial mounds (17). In most areas this is done to protect the buildings from floods, but its widespread prevalence in relatively dry areas too may be an indication that its use is not only a functional one, but is rooted in stylistic adaptation due to cultural precedence.

At the time the earthen walls are erected in layers, openings for doors and windows are retained. The soil is taken from the site or brought to site and prepared there into a cohesive mixture, with straw or rice-husk additives to provide strength during drying and shrinkage. The surfaces of the earthen walls are plastered with a layer of mud slurry mixed with cowdung to achieve a smooth finish. This plaster is regularly maintained and requires frequent attendance in the rainy reason.

b. Construction with large earth blocks: This is a variation of the layering technique, where instead of a series of continuous longitudinal strata, large earth blocks are made and lifted into place, to be laid in successive layers. As each layer built of the large earth blocks

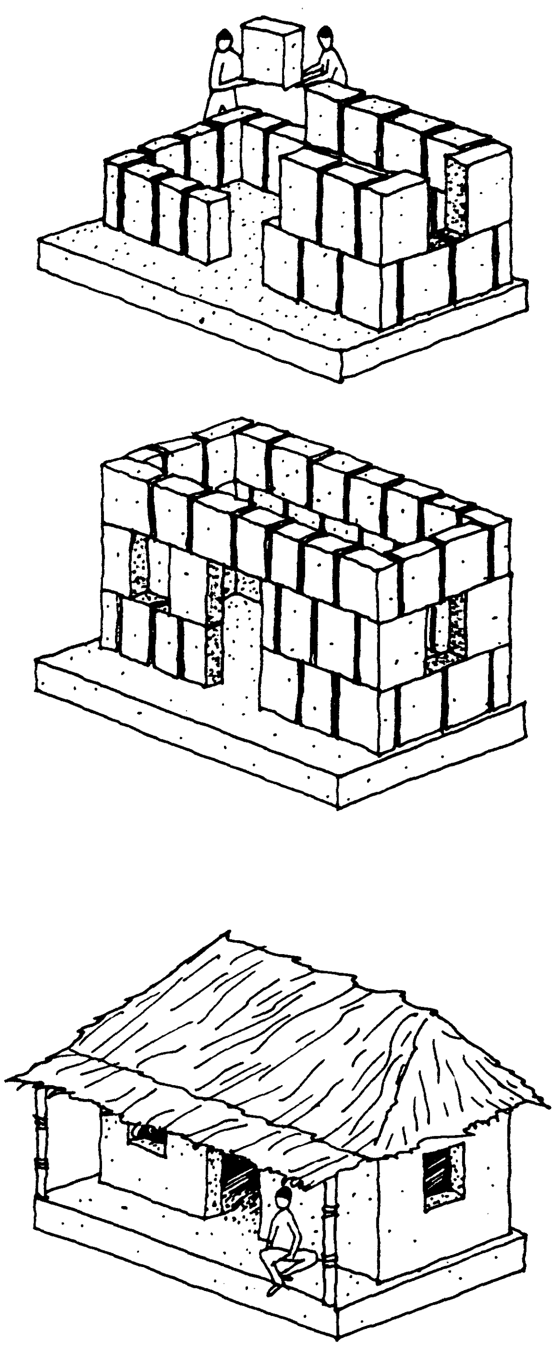


Fig. II.13. Wall construction technique with large earth blocks.

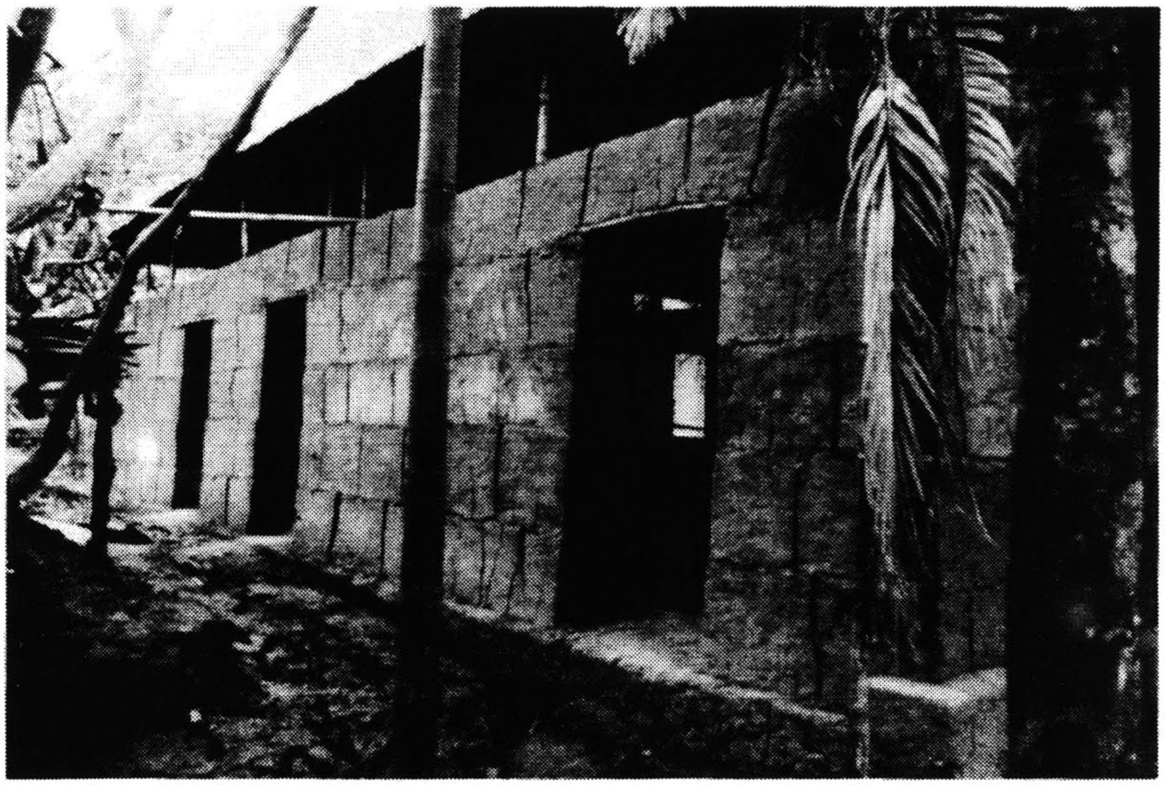


Fig. II.14. Wall being constructed with large earth blocks.

dries, the next layer is built. Documentation of this technique in the north of Dhaka has been provided by Hasan (18). Vertical gaps are kept between the earth blocks, which become larger gradually as the earth dries and shrinks. After the walls have been completely erected and dried, the gaps are grouted with mud mortar, and then the surface is plastered to a smooth finish.

c. Sun-dried bricks: The use of sun-dried bricks is not rooted in indigenous house building practices. Prior to British colonial rule they were used in religious buildings such as temples (such as in Vishnupur, West Bengal) and mosques, of which many historical examples exist at present. The British adopted their use in domestic and institutional buildings. Williamson´s accounts from the nineteenth century provide information about the use and production of sun-dried bricks.

> "Most of the bungalows built by Europeans are run up with sun-dried bricks; usually of a large size, eight of them making a cubic foot; each being a foot long, six inches broad, and three inches thick... Bricks are generally made in wooden moulds, which, being laid on some level spot, previously swept... are filled with mud; the surface is then levelled, with the hand, or with a strike, when the mould is raised, by means of handles, and washed in a pan of water, and then placed on a fresh spot... An expert labourer will, if duly supplied with mud and water, make from 2000 to 2500 bricks daily... one labourer mix(es) the soil, one suppl(ies) the water and two hand-barrow men keep one brick-maker in constant work;" (19)

This mode of production has continued to the present day. However, this practice of making sun-dried bricks is

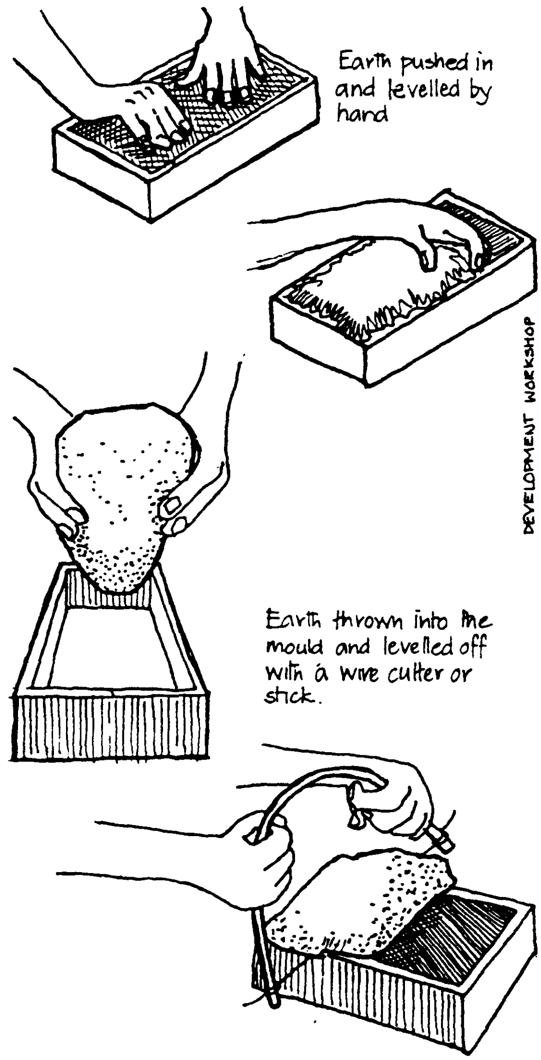


Fig. II.15. The process of making sun-dried bricks.

evidently endemic to the less flood prone regions, as it requires dry ground for working with the molds. For this reason it is uncommon in the more flood prone regions.

Even in houses built with sun-dried bricks, a raised plinth of rammed earth is first constructed and then the bricks are laid in mud mortar. In most cases lime, and sometimes asphalt, is used on the exterior surface as finishing for rain protection.

d. Wattle and daub: This is quite uncommon in the Pleistocene Uplands. However, Hasan has written about some evidence of this technique in the area. He has described the construction as "Wattle type with bamboo or wooden post inside the walls" (20). In any case this is certainly not a widely prevalent mode of construction and I will not dwell extensively on this method here. The only conclusion I am inclined to draw from here is that the prevalence of the wattle and daub system in other areas of Bangladesh is the influencing factor for buildings to be built in this method in this area, where traditionally earthen buildings are built in the layering technique.

It may be pertinent to mention that in any particular settlement there is a range of building forms based on their materials and methods of construction. This is undoubtedly a contemporary development occurring due to the advent of newer materials and techniques. In former times, a homogeneity of building materials and form would exist in a particular settlement or village. That is, for example, where the layering technique existed, all the dwelling units would be constructed in that technique in the entire area. Of course, there was always the difference among the houses of the rich and of the poor, but this was more so in terms of size of property and dwelling unit, number of buildings and such, and not in terms of building material. In some cases, the wealthy had earthen houses while the poor lived in houses made from straw hurdles (21).

In the present age, any particular settlements yields a motley assortment of house forms. The layout may be similar and in keeping with traditional layouts, but in terms of building materials there is large diversity. A survey of a village in the north of Dhaka yielded results which demonstrate this diversity. Various combinations existed between walls made of earth/bamboo/jute sticks/bricks/C.I. sheet and roofs of thatch/C.I. sheet (22). However, almost all the floors of the houses in the village were of the bare rammed earth type.

This particular notion of variety is important to bear in mind during this discussion of house forms. As this thesis deals primarily with earthen buildings, while describing the earthen architecture of a certain region I do not intend to encompass the whole range of building types in that region. It is possible that where a particular earthen construction technique can be found, that technique was the prevalent building mode in that area before the advent of more modern building materials. Any rural development scheme must recognize this transition from homogeneity to heterogeneity of construction methods, and must attempt to incorporate the essence of this change in planned interventions.

II.3.2. Recent Plains:

The plainlands have been formed by the successive sedimentation of alluvial deposits. More than 75 % of the land in Bangladesh belongs to this category. There are regional variations and the Recent Plains have been subdivided into areas designated as the Piedmont Plain, Flood Plain, Deltaic Plain, Tidal Plain and Coastal Plain. In general this is flat and low land, with the plains in the coastal areas more so in nature. Most of this land is vulnerable to periodic floods.

Most of the vernacular architecture of this region consists of buildings which employ bamboo as the primary building material. Bamboo is abundantly available in most parts of Bangladesh, and this available resource has been utilized to develop a highly refined bamboo technology for building construction. Based on accounts of the traveller Francis Buchanan in the nineteenth century, Anthony King has written about the bamboo architecture of Bangladesh:

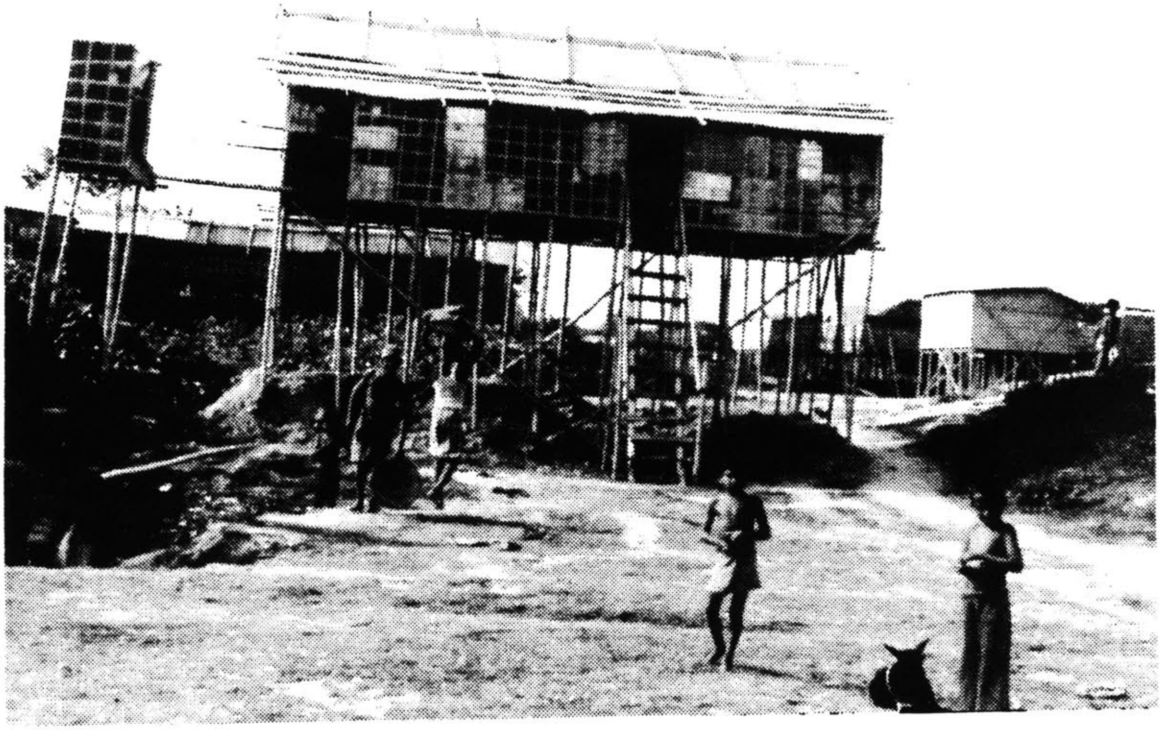


Fig. II.16. Bamboo architecture is highly developed and widespread in Bangladesh.

"Where the soil was too loose for making walls, the sides of the hut were formed of hurdles made of straw grass or reeds confined between sticks or split bamboos, tied together. In the better kind of houses, in place of straw, hurdles made of mats were used, or those of straw were plastered with cow dung and clay." (23)

This particular description is a key for understanding the bamboo architecture of Bangladesh. I will begin by analyzing it. If the soil is too loose for making walls it may be that it contains too much clay - which is true for the alluvial soil of Bangladesh. Soil in alluvial flood plains is usually clayey (24). Due to its properties of shrinkage during drying, it is difficult to build monolithic walls with clayey soil, as the walls develop serious cracking (25). This is probably the reason for building in some areas in layers with large earth blocks with gaps between them, as has been described above. In any case, the unsuitability of local soil for building in the familiar layering technique prompted the development of alternative building materials - namely bamboo, straw, reeds and such other locally available materials.

The British use of the word "hurdle" is intended to mean a portable wall panel (or fencing) made of intertwined branches or wattle. This wattle is held in place by a bamboo frame and bamboo laths. In some cases, instead of wattle, mats made of interwoven split bamboo is used. This is quite common, and mats can be found in a wide variety of weaving techniques.

The important piece of information is the fact that sometimes the hurdles or mats are plastered with cow dung and clay. This, of course, is a version of the wattle and daub system. Cow dung is used as an binder for clayey soil; it is a common practice all over the Indian subcontinent. Hasan has also provided information on this rudimentary form of wattle and daub system in rural Bangladesh. While he has commented that the "Thatch" house (which is the bamboo architecture being discussed) is the "basic traditional house for its extensive use all over rural Bangladesh" (26), he has also reported on the wall building technique of this type:

> "these walls are non-load bearing and strictly speaking, are wall covering panels used in conjunction with the frame structure of the house. Jute sticks, reeds and rice straw are usually used with mud plastering on one or both sides." (27)

Bamboo architecture is the well adapted climatic response for the creation of shelter from local resources. The porous screens of the bamboo mats allow adequate cross ventilation for the interior of the building in the hot-humid country. However, they also allow the chilly winds to penetrate during the cold season, as well as the rainwater during heavy torrential rainfall. For this reason, I would surmise that the inhabitants of these buildings attempt to plaster them as a protective measure. Possibly areas of the buildings exposed to rain or to cold winds are the ones which are plastered. In some areas as observed by Hasan

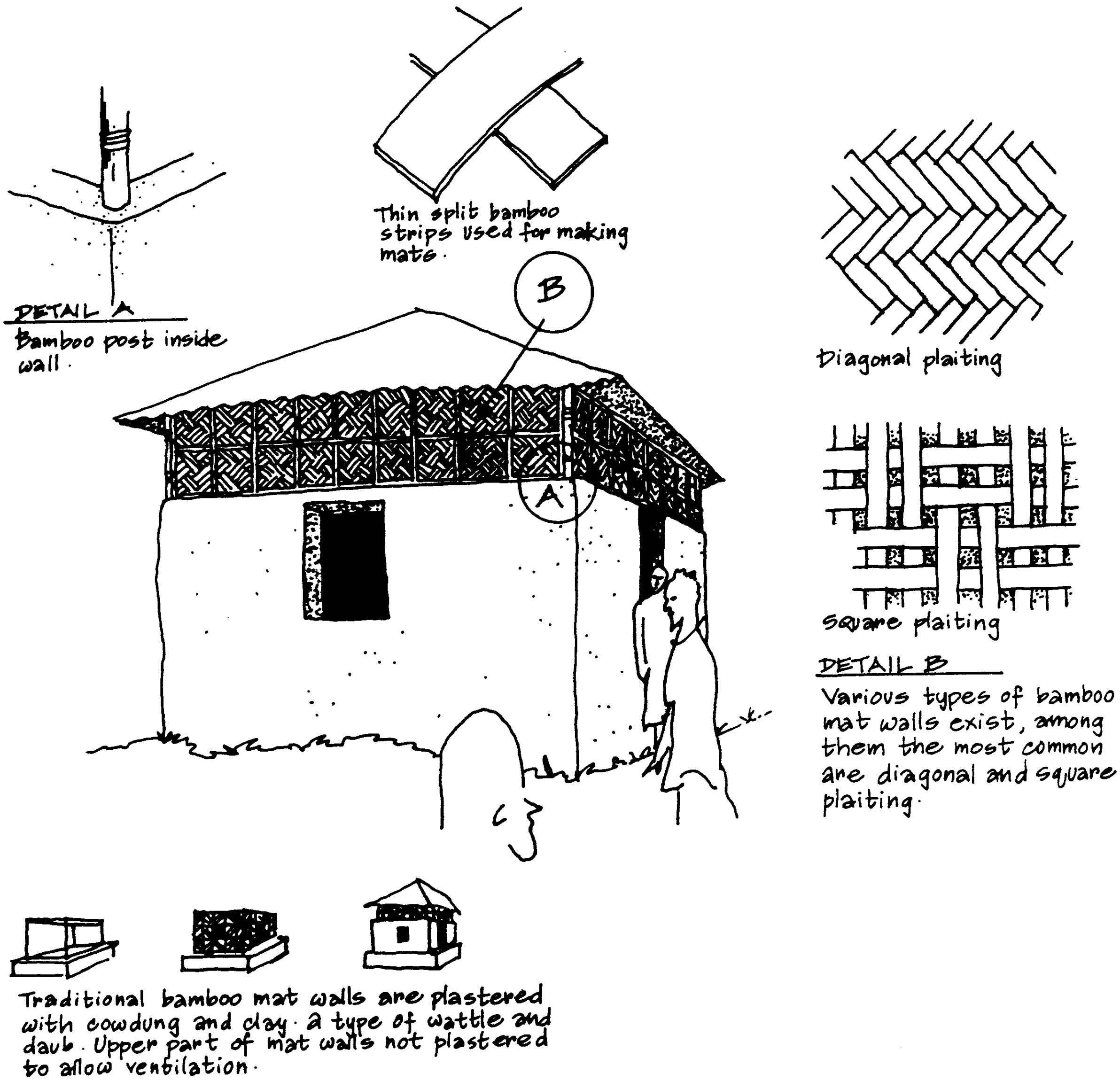


Fig. II.17. Bamboo mat walls with mud-plaster: similar technique as wattle and daub.

Fig. II.18. Splitting bamboo to make thin strips for weaving mats and making baskets.

(28), there are examples of houses which are part earthen and part bamboo screened. The combination of these two materials - bamboo and earth - have created a local vernacular idiom.

Bamboo buildings in the coastal areas are subject to high wind velocity and stormy weather. The tensile strength of the bamboo frame is often suitable for resisting these environmental stresses. But this is not true in all cases. In areas with extreme conditions of the environmental stresses the bamboo frame may be susceptible to great damage. Possibly for this reason, plastering is done to provide sturdiness to the structure.

Even in this form of architecture a raised plinth of rammed earth is constructed, with a bare earthen floor. The roof may be of thatch or C.I. sheets supported on a bamboo or wooden roof frame.

Examples of a well developed wattle and daub system do exist in some parts of the plains, notably in the marshy lowlying area of Sylhet (Haor region). The system is locally known there as the "Ekra" house (29). The area experiences heavy rainfall annually, and hence the wattle and daub system has been developed so that the entire wall is not washed away in the rain. After heavy rains, the wattle frame can be re-plastered and easily repaired.

Hasan has provided information on this type of construction (30). A wooden frame is built and then the

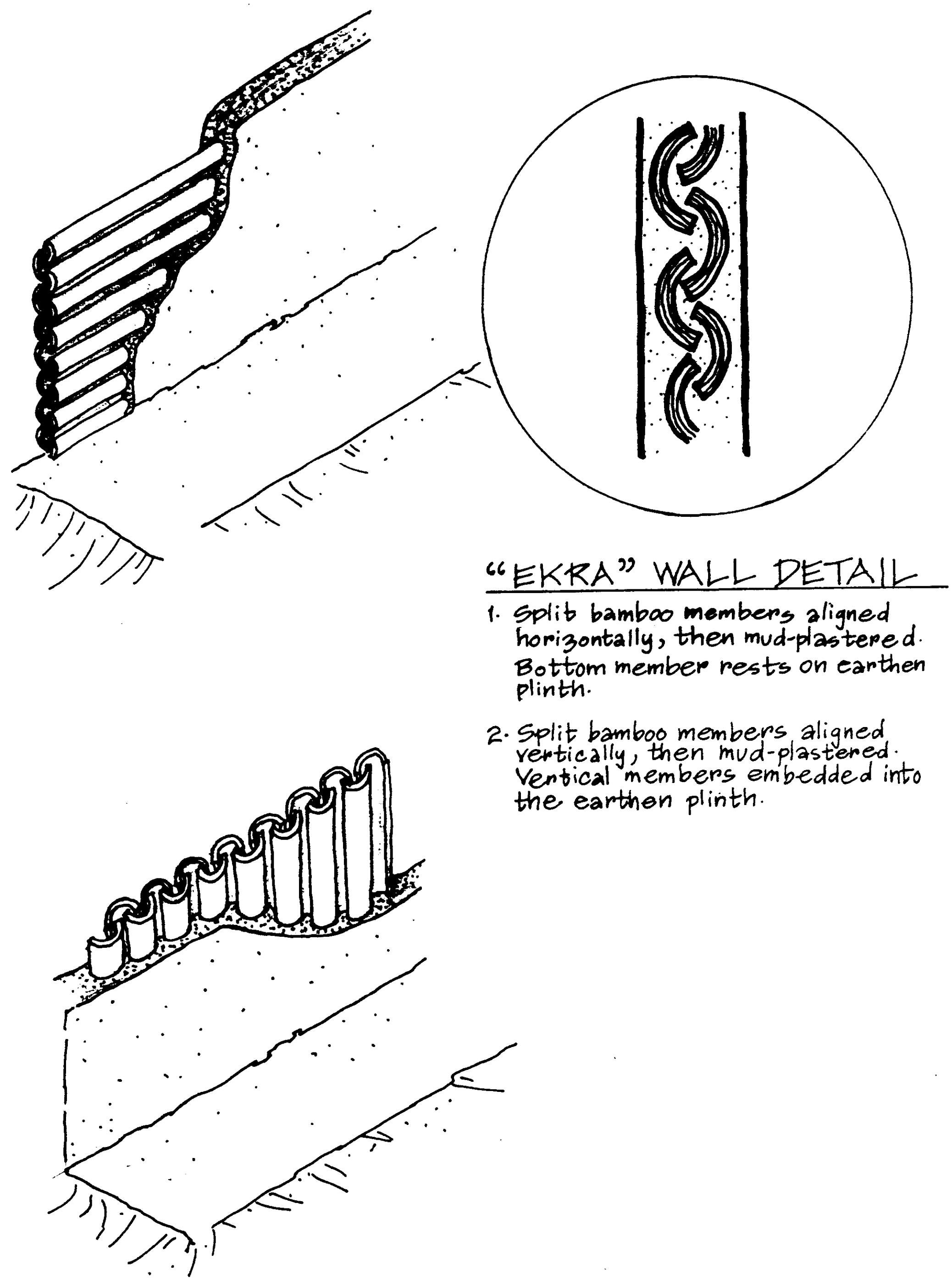


Fig. II.19. "Ekra" wall construction in Syhlet, a type of wattle and daub.

gaps between the frame are filled in with interwoven bamboo laths or bamboo mats. Then soil plaster is applied on both the exterior and interior surfaces.

Even in this type of construction, a raised rammed earth plinth is built. The bottom members of the wooden frame rest on this plinth, while the vertical members are embedded into the plinth to provide stability to the frame.

II.3.3. Tertiary Hills:

The only hilly area of Bangladesh is the Chittagong Hill Tracts in the south east. There are also some scattered hills in the Sylhet region, but this is on a much lesser extent. The hills are low, having an average height of 1000 feet (about 300 meters). Most of the population in the hilly area are tribal and are socio-culturally somewhat different from the people in the rest of the country.

Hasan has provided information on the vernacular architecture of the hilly region (31). Because of the uneven terrain, buildings are raised on stilts, to site them on the hilly slopes. Here the rammed earth plinth is uncommon. The platforms raised on stilts serve as the floor and are usually constructed out of wood or bamboo. The prevalence of earthen buildings is less in this area, the predominant building material being bamboo, thatch or wood.

Some examples of earthen buildings constructed out of sun-dried bricks exist in some parts of the hilly region.

Fig. II.20. Houses on stilts in the hilly region.

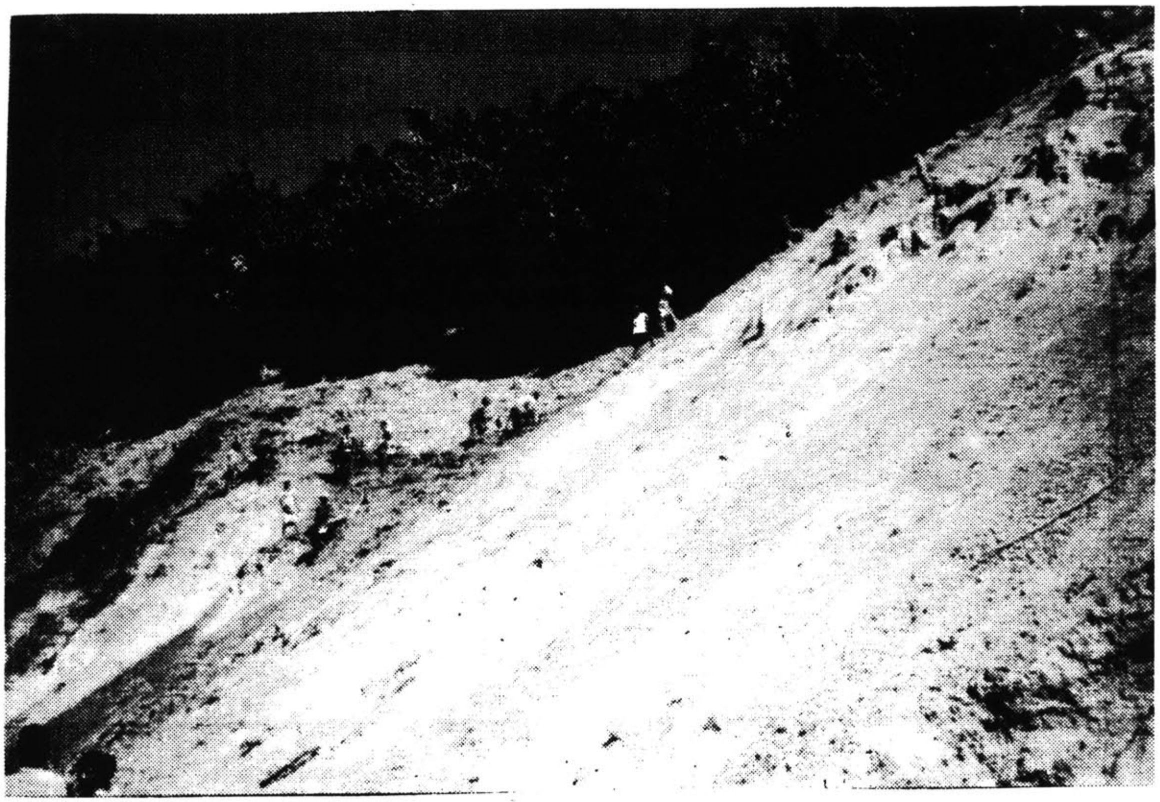


Fig. II.21. Deforestation followed by consequent hillside erosion is a serious environmental problem in the hilly region.

Being at a higher elevation and less prone to floods, this area offers the opportunity to use the ground as working space for the production of sun-dried bricks. Excellent examples of even two storied earthen buildings exist in the hilly area.

This area which has distinctly different characteristics from the rest of the country deserves a separate treatise. A comprehensive discussion of its architecture would be beyond the scope of this thesis. Nevertheless, one important fact needs to be brought to attention. In recent years, the hilly area is undergoing a severe deforestation. The supply of wood for building purpose is in short supply. For this reason, sun-dried bricks need to be promoted as an alternative to the more widespread use of timber technology. This is already a well known practice in the area, and attempts at improving the architecture of the area need to provide more incentive for the use of sun-dried bricks.

II.4. SUMMARY:

Bangladesh is situated in a large deltaic region with a characteristic hot-humid climate. Adverse environmental conditions resulting from annual floods and periodic storms are a sources of hardship for the people. Predominantly rural, the country has a high population and is among the most densely populated, and also among the poorest countries in the world.

There are well developed vernacular building forms in rural Bangladesh, but these are undergoing rapid change due to the introduction of imported, industrialized building materials. The use of corrugated iron sheets has become quite popular and widespread, and the use of traditional building materials and their manufacture is diminishing consequently. However, C.I. sheets have serious disadvantages, leading to the need for the revival and development of more suitable building materials.

Vernacular architecture has evolved in Bangladesh corresponding to the three main physiographic regions. Four main techniques of building with earth exist in these regions: the layering technique, building with large earth blocks, sun-dried bricks and wattle and daub. The wattle and daub technique exists in a well developed form in some places, but generally it is a simply a matter of plastering bamboo mat walls with mud. This technique adds sturdiness to the otherwise flimsy though highly developed bamboo construction techniques.

------------------------- NOTES ----------------------------

1. Rabindranath Tagore, The Cresent Moon: The land of the exile," in Collected Poems and Plays of (The Macmillan Company, New York, 1956), stanza 4. lines 1-5.

2. Gilbert M. Grosvenor (ed.), National Geographic Atlas of the World (National Geographic Society, Washington D.C., 1975), p.22.

3. Most of the information in section II.1. has been adapted from several sources. Among them the most important are, the Bangladesh Ministry of Information, External Publicity Wing, Bangladesh Diary 1990 and, Aminul Islam and Maniruzzaman Miah (ed.), Bangladesh in Maps (World University Service Press, Dhaka, Bangladesh, 1981).

4. The description of the Bangladeshi rural house and settlement pattern has been adapted from different sources, as well as personal observations. The important references in this regard are both of Dewan Mahbub Hasan's master's theses. The first one is "A study of traditional house forms in rural Bangladesh" (Master of Architecture thesis, Bangladesh University of Engineering & Technology, 1985), and the second one is "Building process of houses in rural Bangladesh" (Master of Engineering in Architecture thesis, Katholieke Universiteit Leuven, Belgium, 1987).

5. Not much has been written about this demographic change as related to pottery products and specialization. The information presented in this thesis has been obtained from verbal descriptions of the phenomenon by older members of Bangladeshi society. A reference to this demographic phenomenon has been made in the thesis of Hasan, "Building process of houses in rural Bangladesh," p.60.

6. R.J.S. Spence and D.J. Cook, Building Materials in Developing Countries (John Wiley & Sons Ltd., New York, 1983), p.285.

7. Hasan, "A study of traditional house forms in rural Bangladesh," p.62.

8. B. Givoni, Man, Climate and Architecture (Applied Science Publishers Ltd., London, 1976), p.107.

9. Otto Koenigsberger and Robert Lynn, Roofs in the warm humid tropics (Lund Humphries, London, 1965), p.29.

10. Hugo Navarro, "Earth construction technologies applied to the humid tropics", Architectural Institute of Japan, Report on the International Symposium on Earth Architecture (Beijing, China: n.p., 1986), pp.214-215.

11. Anthony D. King, The Bungalow (Routledge and Kegan Paul, Boston, Mass., 1984), pp.18-22. King has provided accounts of the indigenous architecture of pre-colonial and colonial Bengal, based on the reports of travellers in the

region, such as, Comte du Modave, Francis Buchanan, Captain Thomas Williamson and Nilsson.

12. This concept has been proposed by Prof. Reinhard Goethert at M.I.T., Cambridge, based on his experience in a housing project in Zambia. In that project, it was initially conceived that CINVA-Ram earth blocks would be used for building houses, and the blocks were made available to the project beneficiaries. However, the beneficiaries did not prefer the blocks, which were then used to build a school. This use served to highlight the attractiveness of the blocks - consequently the beneficiaries began using the blocks to build their houses.

13. Pise is another name for the technique more commonly known as "rammed earth". There are various types of pise construction methods. Descriptions of these techniques can be found in the book by Jean Dethier, Down to Earth (Facts on File, Inc., New York, 1983), and also by Jeffrey W. Cody, "Earthen Walls from France and England for North American farmers, 1806-1870", Getty Institute for Conservation, Proceedings of the 6th International Conference on the Conservation of Earthen Architecture (Adobe 90 Preprints) (Las Cruces, New Mexico: n.p., 1990), pp.35-43. Pise is somewhat different from the layering technique with regard to no forms being used in the latter. They are similar because in both techniques, the walls are built in longitudinal strata, each stratum drying before the next is added.

14. King, p.20.

15. Hasan, "Building process of houses in rural Bangladesh," p.90.

16. King, p.28.

17. Hasan, "A study of traditional house forms in rural Bangladesh," pp.32-35.

18. Ibid., p.70.

19. King, p.30.

20. Hasan, "A study of traditional house forms in rural Bangladesh," p.58.

21. King, pp.19-20. The descriptions of the rural affluent and poor house types have been adapted from Francis Buchanan´s accounts from the last century.

22. Nazrul Islam, Khadem Ali and Shahnaz Huq, "A survey of housing in a Bangladesh village," Proceedings of The Regional Workshop on Transfer of Rural Housing Technology (Dhaka, Bangladesh: n.p., 1981). This survey of a single village in Bangladesh yielded a variety of building techniques and materials.

23. King, p.19.

24. George B. Sowers and George F. Sowers, Introductory soil mechanics and foundations (The Macmillan Company, New York, 1970), pp.45-48. A description of the type of soil common in areas composed of alluvial deposits has been provided here.

25. Magnus Berglund, Stone, Log and Earth Houses (The Taunton Press, Inc., Watertown, Connecticut, 1986), p.103.

26. Hasan, "A study of traditional house forms in rural Bangladesh," p.60.

27. Ibid., pp.60-62.

28. Idid., p.195.

29. Ibid., pp.156-160.

30. Ibid.

31. Idem, "Building process of houses in rural Bangladesh," p.55.

CHAPTER III

"Many great civilizations have to contend with restrictive ecosystems. They succeeded by making the best, often to excess, of what they could get from the environment. Human ingenuity is proficient in turning necessity into virtue and then breaking the boundaries of restraint, triggering disaster." (1)

III. HOT-HUMID CLIMATES AND ARCHITECTURAL RESPONSE

III.1. CLIMATE AND FORM:

I will begin this chapter with the inquiry regarding the importance of climate, as the factor influencing building form, in hot-humid areas. Though most architects and theoretians agree about the dominant role that climate plays in giving shape to traditional buildings, Amos Rapoport differs on this viewpoint. According to him, there is a variety of factors which are responsible for determining building form, among them socio-cultural factors and construction, materials and technology factors, along with climate, being the prime ones. He has provided a number of cross-cultural examples where climate played a much less significant role in determining building form, as compared to other factors, which had a more dominant role (2).

None the less, he has also conceded,

> "While I have suggested that climatic determinism fails to account for the range and diversity of house forms, climate is, nevertheless, an important aspect of the form generating forces, and has major effects on the forms man may wish to create for himself. This is to be expected under conditions of weak technology and limited environmental control systems, where man cannot dominate nature but must adapt to it." (3)

This is exactly the case in Bangladesh. The inability to control nature by means of a powerful technology (which is the result of a strong economy), has led to building forms which respond directly to climate. A comparative analysis of indigenous building forms in different parts of the world would reveal results which concur with Rapoport´s concept. For example, if we choose cases in other hot-humid areas which have a similar level of technological development as Bangladesh, and are also comparable in terms of economy and socio-cultural conditions, the indigenous architectural responses in all the cases would tend to reflect a high level of similarity. However, if we compare cases which have a great divergence in terms of technology, economy and socio-cultural factors, yet are climatically similar, the architectural responses would be quite different in nature. For instance, if Florida in the U.S. is compared to Bangladesh, in spite of both being similar hot-humid regions, the pattern of response to climate through architecture is indeed quite different.

Human beings´ basic response to climate is to adapt to it, and to control it in such a way that spaces used for habitation and work are free from environmental stresses. Technology is the basic tool for this control of nature. The most primitive shelter to provide protection against the elements is the first step in this direction. Gradually, this rudimentary form is modified through time, based on the level of technological development and availability of materials. For the sake of developing this line of thought, I will for the moment disregard Rapoport´s "anti-climatic" responses (4).

In Florida, as in most parts of the U.S., the architectural response to climate is not in terms of the building form, but through the extensive use of climate-modifying mechanical devices. Poor countries like Bangladesh simply cannot afford such devices, and hence cannot ignore climate. The architectural responses there are attempts to achieve harmony with nature, by means of the limited technology and materials available.

The preceding chapter has described the advent of galvanized corrugated iron as a building material in Bangladesh. With the rise in the technological level, new industrialized materials are preferred to traditional ones. But is this a appropriate response? The development of the industrialized countries of Europe and North America provides lessons both in the enchanting possibilities of technology, as well as in its negative effects on society, if society chose to allow it to dominate. The writings of E.F. Schumacher and Ivan Illich are noteworthy in their incisive criticisms of the detrimental effects of technology (5). Aldous Huxley has written apprehensive novels about societies completely dominated by technology, with humans reduced to alienated and lonely beings (6). These writings are over-reactions to contemporary state-of-affairs, no doubt, but they certainly contain distinct traces of honest assessment.

During the last twenty years, the specter of an energy depleted planet has come into focus for the first time in human history. The environmental crises which is presently threatening humanity, is the direct product of technological development. Environmentalists blame the industrialized countries for their wasteful practices and profit-oriented modes of operation. None the less, the fact remains that technology is certainly not the magic genie as it was once believed to be and cannot solve all the problems of the human race. In fact, in many ways it has turned back on itself, and is threatening the existence of the human race.

The evidence of the downfall of technological optimism should serve as a deterrent to less industrialized countries trying to follow in the footpaths of the industrialized West. The abandonment of highly refined indigenous building form, materials and techniques, in pursuit of an ideal, permanent and modern building form may yield poor results and may contribute directly to the global environmental crisis. The alternative would be to base change on existing pre-industrial, natural and locally evolved concepts. This is not simply a nostalgia for the past, or an impulse to preserve aspects of the past as museum pieces. Rather, it is motivated by the need for a healthy and harmonious future, which will form a continuum with the past, not an abrupt and hasty departure.

The appearance of the vernacular buildings in Bangladesh has changed with the introduction of the new material C.I. sheet, but the layout, floor plans and settlement patterns have remained quite identical to traditional types. Merely the surface qualities of the architecture change with the change in material and construction techniques. Rapoport has termed materials, construction and technology as modifying factors of form : "Materials in themselves do not seem to determine form." (7) According to him, culture is the main determinant of form, and the rest, i.e. economy, materials, defense, climate and so on are modifying factors.

Numerous examples can be provided that demonstrate that any one (or all) of the "modifying factors" often serve as the primary determinants of form and culture, based on the environment, and culture plays a subsidiary or less significant role. The example given above from Florida demonstrates that architectural form is influenced by the economic/technological level and has been determined to a much less extent by culture. Therefore, I suggest that building form is a composite product of various factors, and each is given priority according to the context and situation. The essential priority of architecture is to provide protection from the elements. The responses thereby become modified through time and vary according to the

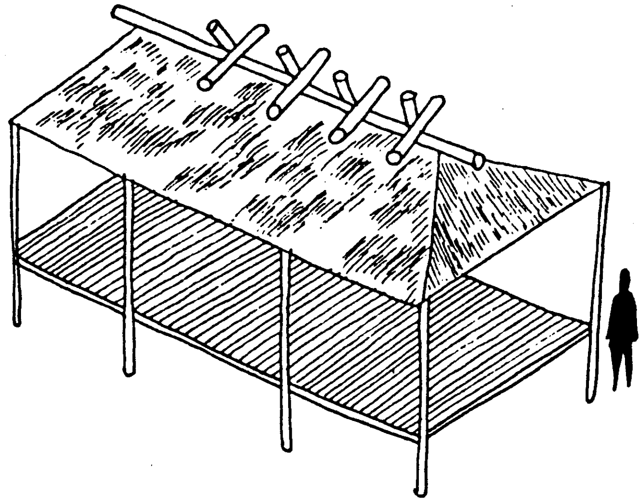
Fig. III.1. Building form remains similar, only the surfaces change with the advent of new materials: Use of C.I. sheet in Bangladesh.

culture, economy or technology, among many other factors. The Seminole house of the native Americans in Florida is an example of the typical response to climate in hot-humid areas (8), when compared to responses in other similar regions. But the contemporary houses in Florida have been very much modified through time, with the factor of economy/technology playing the vital determining role. Their form is indeed quite different from the indigenous Seminole house.

The extremes of climate in Bangladesh are more compelling than many regions of the world. The adverse climatic conditions, coupled with the high level of poverty pose serious constraints on architectural design. The architectural response to climate throughout the past in rural Bangladesh has managed to evolve highly developed forms based on those constraints. Utilization of limited available resources have produced regional varieties of vernacular architecture. Nevertheless, caution should be exerted when extolling the virtues of Bangladeshi rural architecture; excessive romanticizing may distort perspectives. Hasan has pointed out this fact,

> "probably very little is known about the shortcomings of housing in rural areas, and it would be a mistake to idealize the conditions in which it was possible to satisfy needs, or the quantity of the dwellings built." (9)

There are serious problems with vernacular buildings all over the world. A study done at the University of



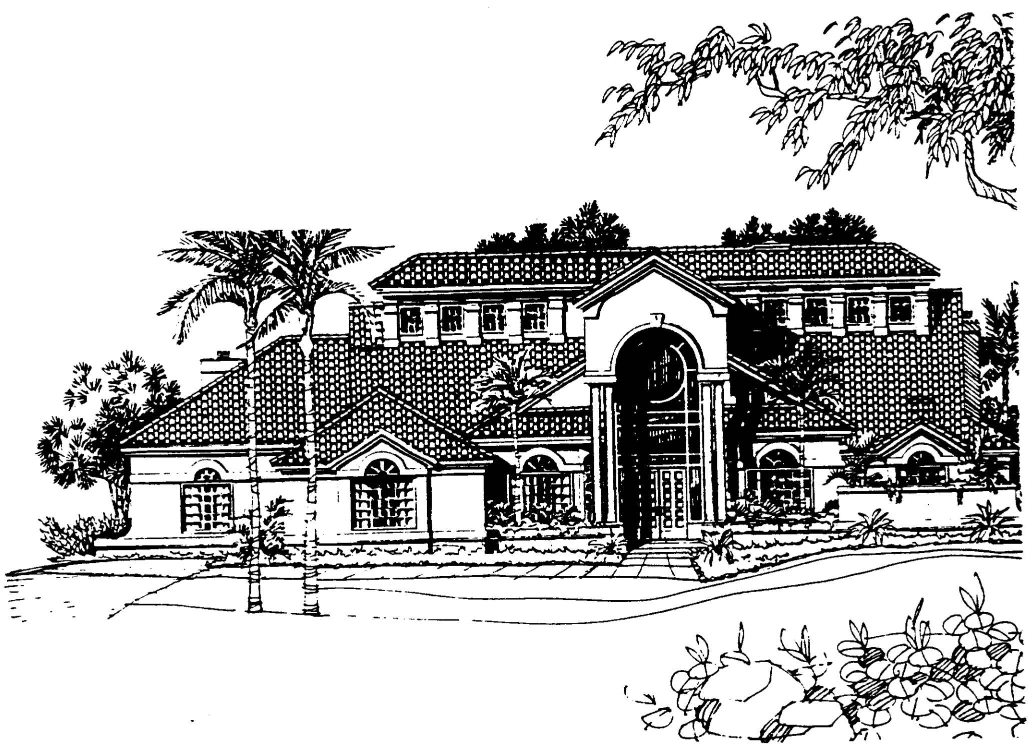


Fig. III.2. A Seminole house and a contemporary house in Florida. The first, a climatic response when technology was not available, the second, a response based on A/C technology.

Melbourne showed that the thatch roofs in New Guinea shed particles which cause chronic allergic lung diseases. The wattle and daub buildings in South America harbor disease carrying insects (10). Our standards of safety, hygiene, health, as well as psychological well-being has gone through great change from traditional notions about these issues. If the present day vernacular building is required to fulfill these standards, they have to go through change as well. Their architectural principles have to be preserved and the essence of their accomplishments have to be distilled and transmitted to subsequent transformations, which in turn are likely to arise from within the vernacular idiom, not from without.

III.2. TYPICAL RESPONSES IN HOT-HUMID AREAS:

In this section I will analyze the writings of a few notable authors, who have described the architecture common to certain climatic zones. For relevance to this thesis, I have chosen to discuss their writings regarding architecture in hot-humid areas in general. Their treatises on this topic reflect a high degree of concurrence, which is predictable, but it is not my intention only to demonstrate this concurrence, but also to investigate how much of it is concurrent with vernacular architecture in Bangladesh.

III.2.1. Orientation:

Victor Olgay has written,

> "In the southern hot-humid region the sun attacks the east and west ends of a house and forces it into a slender elongated structure.... Free plans can also be evolved here, as long as the house is under protective shade." (11)

The traditional rural building in Bangladesh is rectangular and elongated in shape, with the elongated sides oriented facing the north-south direction. The western side usually has very few openings, and this prevents the late afternoon radiation from penetrating into the interior of the buildings. The elongated side, facing south, provides the necessary light and breeze for daytime activities, which tend to spill over into the adjacent open courtyard. The north side has smaller openings to prevent the flow of chilly winter northern winds, yet allows sufficient cross ventilation to occur during warm and muggy periods.

The traditional layout in rural areas of Bangladesh tends to consist of a number of such elongated buildings clustered around an open courtyard. Hasan has attributed the development of this form of courtyard layout to certain socio-cultural factors, privacy being one of the main factors. But, as Olgay has stated, variations of the elongated plan works well under protective shade; similarly Hasan has also written,

> "certain socio-cultural preferences which generated a court yard layout with orientations of the huts in all the cardinal directions. Because of the low height of the house structures and an abundance of trees

available for shading, the ill effects of solar radiation owing to wrong orientations of the structures is considerably reduced."(12)

The low height is definitely a characteristic feature of the rural buildings in Bangladesh. In many cases, entry into the domain of the building is accomplished through bending the body lower. The abundant vegetation is characteristic of all hot-humid areas. The thick foliage works marvelously as a shading device for the buildings and also provides ample outdoor shaded activity areas.

III.2.2. Ventilation:

Perspiration (or as commonly known, sweating) is a natural function of the human body which achieves balance between the metabolic heat produced within the body and the dry heat of the surrounding air. At low levels of humidity, the amount of perspiration evaporated from the body equals the amount of perspiration secreted by the body, and this occurs within the pores of the skin without any visible effect. However, at a higher level of humidity, the ability of the surrounding air to absorb moisture and assist in the evaporative cooling of the body is diminished. Thereafter, perspiration comes out of the pores and spreads over the skin and achieves evaporative cooling by spreading over and losing heat to the surrounding air, and also to the clothes, hair and other close objects. By gaining heat from the body and also moisture, the surrounding still air in a closed room becomes saturated and eventually cannot provide the necessary evaporative cooling for human comfort. Therefore, removal of the still air and replacing it with a new supply of air allows further evaporative cooling. As Givoni has written:

> "An increase in the air velocity counterbalances the effect of humidity..." (13)

The removal of air inside buildings is achieved by ventilation. Koenigsberger has written about the vital need for ventilation of buildings in hot humid climates. The only relief available from the climatic stress, which results from high humidity is by wind flow. According to him,

> "In this type of climate buildings tend to have open elongated plan shapes, with a row of rooms to allow cross ventilation. Such rooms may be accessible from open verandahs or galleries, which also provide shading." (14)

As has been mentioned in the preceding section, the elongated shape of the traditional Bangladeshi rural building with its single row of rooms is not only a protective measure against solar radiation, but also a response to take advantage of prevailing breezes to alleviate the interior conditions of humidity. In spite of the buildings not being elongated along the same directions, their clustering around a courtyard allows the suction of breeze into their interiors. It may be noted that all the elongated sides face the courtyard, and for this reason all the buildings facing the courtyard get ventilation.

Much has been written about the verandah of the traditional rural house in Bangladesh. King has proclaimed it as a characteristic feature of the indigenous house in Bangladesh (15). In any event, the typical verandah provides an open, yet shaded zone; being open allows cross ventilation and being shaded provides protection against solar radiation. Broad roof eaves provide shade to the verandah, as well as protection from rain.

Koenigsberger has also noted,

> "Ventilation will also be necessary to the space between the roof and ceiling, and adequate openings must be provided for this purpose." (16)

In many areas of Bangladesh a gap is left between the top of the wall and roof to allow warm air to escape from the inside. In most cases, the roof for the surrounding verandah is a separate structure from the roof of the main building. The space between these two is often endowed with small openings for ventilation. In many cases, there is a "false ceiling" of bamboo mats or wooden planks, and in the poor houses, of gunny cloth made from local jute. Hasan has noted that this is a form of protection from heat radiated downward from the roof and also from insects harboring in the roof. In some cases, this also serves as a storage space (17).

Olgay has written of hot-humid areas, "The houses are separated to utilize the air movement;" (18). The observations of Koenigsberger are also to the same effect.

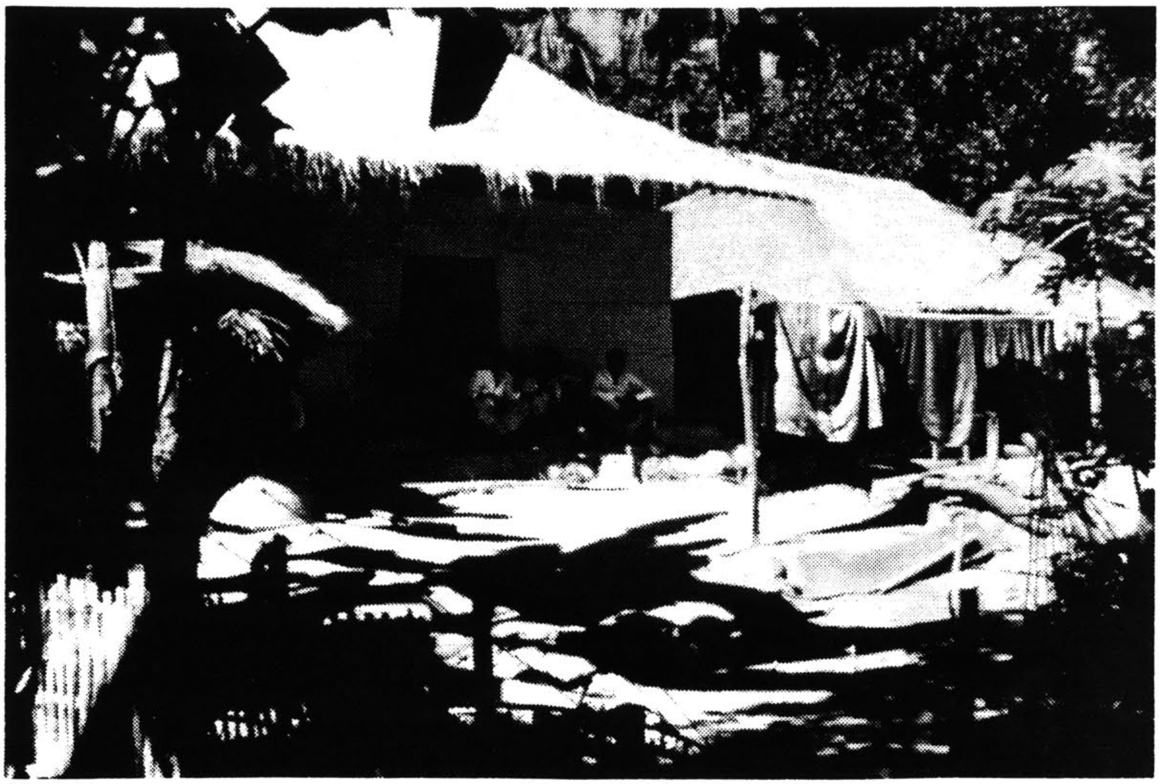


Fig. III.3. Gap between walls and ceiling to achieve ventilation in a Bangladeshi rural house.

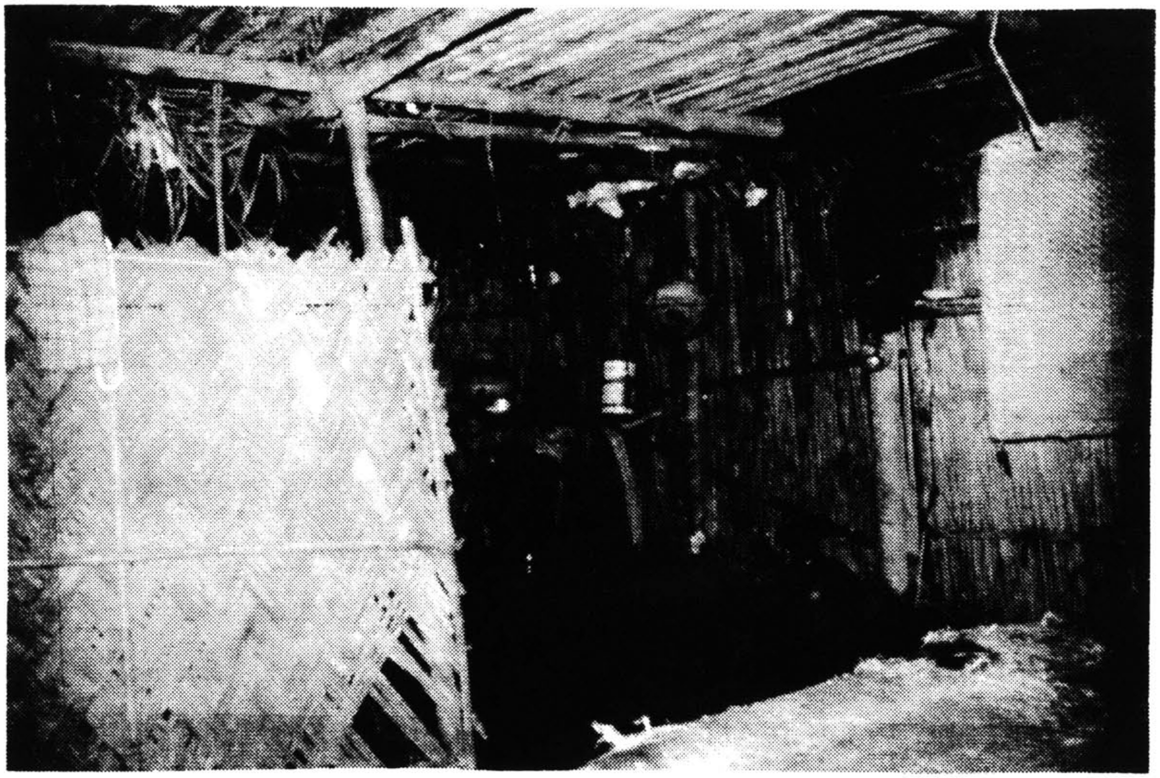


Fig. III.4. "False ceiling" of bamboo.

He has provided a number of reasons for this type of settlement pattern:

> "The density of development in warm-humid regions is always far less than in hot-dry climates for three reasons:
> 1 To allow free movement of air through buildings and through spaces between buildings
> 2 to provide privacy by distance, as walls and screens cannot be used for this purpose (they would prohibit air movement)
> 3 many activities are carried on out-of-doors " (19)

As has been mentioned earlier, the typical rural settlement in Bangladesh consists of individual buildings clustered around an open courtyard. The inter-building spaces serve to ventilate the individual buildings. The courtyard is derived from socio-cultural concepts of privacy. And a large proportion of the daily activities are carried on outdoors, in the courtyard or verandah or other shaded spots. Unlike hot-arid regions, where the density of development is high and individual buildings are grouped very close together as a protection against thermal stress (20), the buildings in hot-humid areas are scattered and widely spaced.

One important fact requires to be stated here. I have described the relationship between evaporative cooling and the need for ventilation to achieve this cooling in humid areas. However, in conditions of extreme humidity and high air temperature, the human body cannot achieve cooling by losing heat to the surrounding air, even if the air is in motion and flowing over the body. In such extreme

Fig. III.5. Density of development is less in Bangladesh than in hot-dry areas. Scattered buildings are grouped around an open courtyard.

circumstances, ventilation does not provide the desirable human comfort. In spite of this fact, some psychological relief may be obtained from the air-flow, even if adequate evaporative cooling does not occur. For this reason, it is important to consider ventilation, even during periods of high temperature and humidity.

III.2.3. Elevated floor level:

The raised plinth is also a characteristic feature of the rural Bangladeshi building (21). The elevated floor of buildings in hot-humid regions is an aspect resulting from three main factors:

1. Flood protection: As has been observed by Rapaport, the reason for constructing raised floors is for flood protection (22). In Bangladesh, homesteads are usually constructed on raised mounds. The sloping mounds serve to drain water off the site in most cases. But sometimes, heavy rain coupled with overtopping of the surrounding river banks result in courtyards becoming waterlogged. It is in these circumstances that the raised plinth performs its function of flood protection.

2. Ventilation: Koenigsberger has noted that plant covering on the ground effectively reduces the velocity of wind flow, and this in turn results in a reduced level of

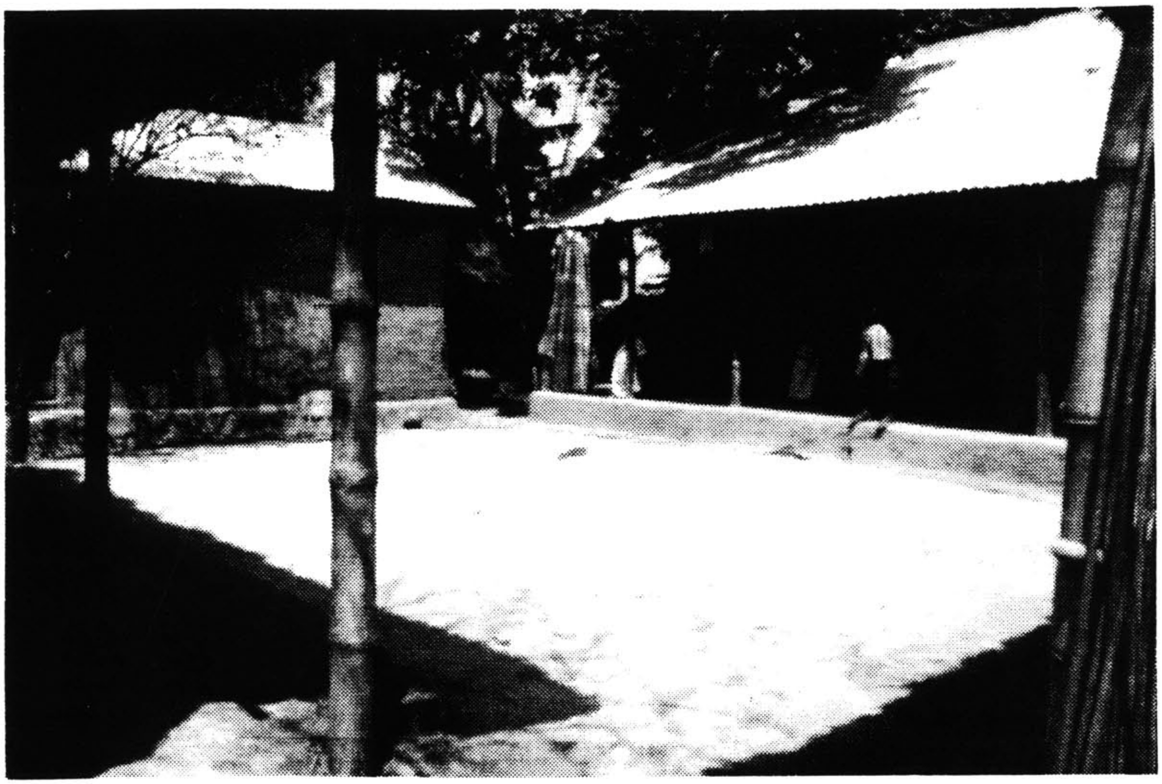


Fig. III.6. The raised plinth: characteristic feature of Bangladeshi rural architecture.

ventilation (23). Thus, raised buildings can take better advantage of the breeze. In many hot-humid regions, buildings are raised on stilts to achieve this effect. Vernacular architecture of Southeast Asia is resplendent in this respect (24). Buildings raised on stilts is not very common in Bangladesh, except for in marshy areas, and also in hilly areas. As has been mentioned in the previous chapter, in the hilly areas because of the uneven terrain the buildings are raised on stilts. It may be interesting to note that in urban areas the rural migrants and low income groups construct the houses in squatter settlements on bamboo stilts. This is for the reason that they often have to situate themselves on waterlogged and marshy land which has low demand for urban use. The rural mode of building upon stilts in marshy areas is applied in urban areas too.

Nonetheless, the raised earthen plinth is a widespread, distinct and characteristic feature in most parts of rural Bangladesh. The availability of abundant earth suitable for building purpose is probably the reason for its utilization to raise buildings for ventilation. The need for ventilation combined with the availability of earth resulted in the raised plinth, which is so common all over Bangladesh.

Fig. III.7. Urban low-income groups build on stilts in waterlogged areas.

3. Protection from vermin: Rapoport has written that the raised floor is also a "defense against the large insect and animal population" (25). This large insect and animal population is endemic to hot-humid regions and Bangladesh is no exception to the case. Apart from the numerous varieties of insects, the raised floor is a protection against crawling vermin, such as snakes and rats. Often this function cannot be fulfilled effectively by the raised plinth; nevertheless, it represents an attempt in that it does serve to deter some of the vermin, if not all.

III.2.4. Building materials:

From the point of view of this thesis this section is a decisive one. Koenigsberger has dealt to some extent with the traditional responses in terms of materials in hot-humid areas (26). According to him there are two typical responses:

1. Where there is a shortage of timber, the buildings are constructed from earth. However, according to him this material cannot function effectively in hot-humid areas as it prevents adequate cross-ventilation and creates thermal time lag. But this is not a completely accurate observation. The nature of the thin earthen walls of rural buildings in Bangladesh (27) does provide a respite from the acute solar radiation, yet the thermal time lag effect is

not so pronounced as in the earthen buildings of arid areas with their thick walls. Providing large openings also allows cross-ventilation through the interior of the earthen buildings in Bangladesh. However, the walls may be constructed so that they are thinner and lightweight. Consideration of such improvement techniques is important in this thesis; I will therefore discuss them in greater detail in a later section.

2. Where the soil is unsuitable for building, the response has been to utilize timber (and/or bamboo) for building construction. Various forms of wall screens and partitions made from bamboo or timber have evolved in such contexts. As has been noted in the previous chapter, there are numerous examples of such buildings in Bangladesh (28). These type of buildings perform quite well in humid areas in terms of cross-ventilation; the porous screens allow smooth flow of breeze from outside to inside and vice versa. Several problems do exist with this type of building, and therefore attention to the problems have to be paid with the intent of overcoming them, and thereby creating an improved architecture.

The typical response to the climate indicate a large degree of concurrence between those in other regions and Bangladesh. This is another credit to the merit of vernacular buildings for responding to climate effectively

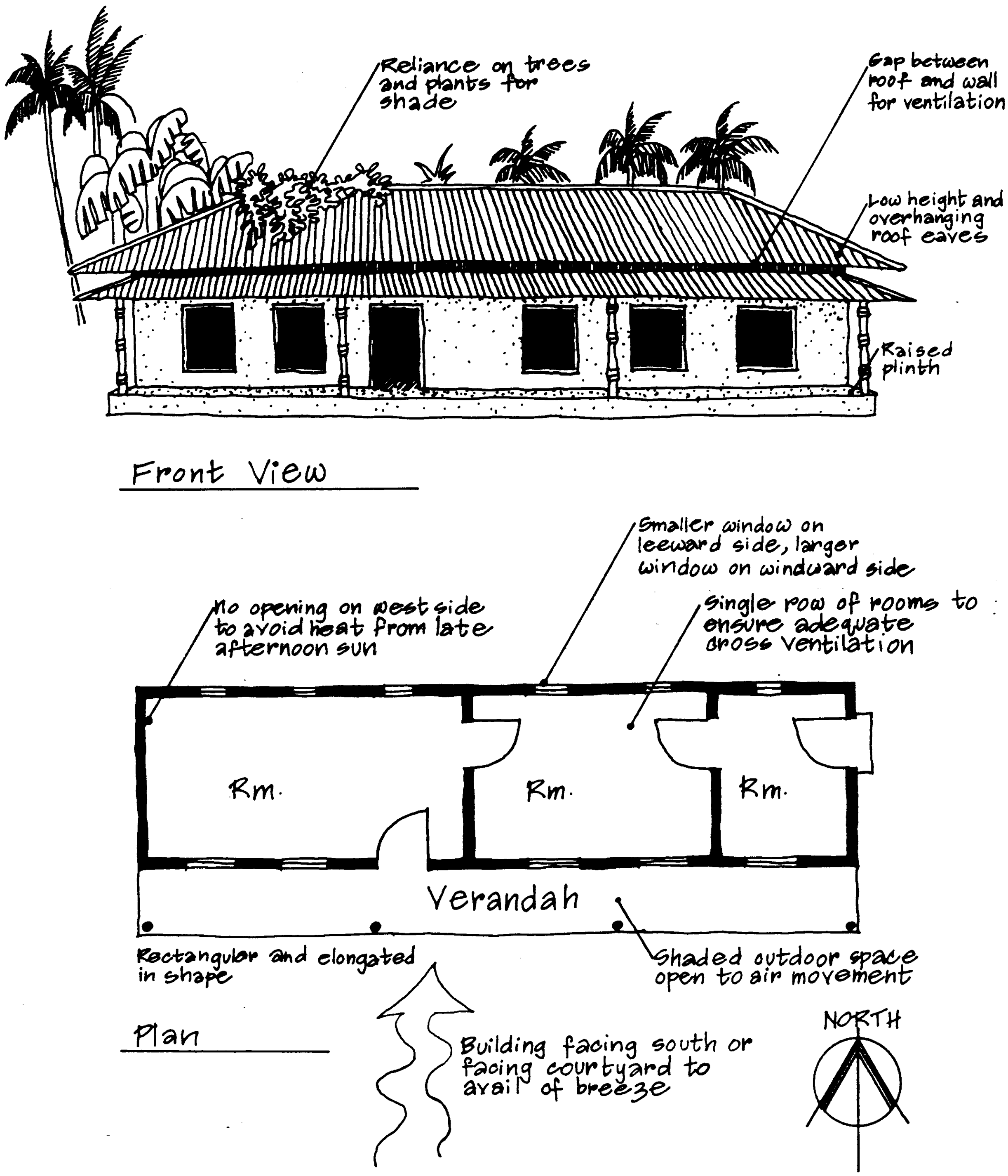


Fig. III.8. Typical house in Bangladesh, showing salient features as related to climate.

in universal ways. In spite of their largely appropriate responses to climate, these responses have, in many cases, either become outmoded or are unable to cope with the demands of the contemporary age, especially with regard to socio-cultural and economic change. In some cases, these climatic responses have been disrupted during the process of their evolution, and were not permitted time to develop to their fullest extent. It is this transformation and the consequent need for upgrading of techniques and materials in the problem areas that this thesis aspires to explore.

III.3. CASE STUDIES - EARTH ARCHITECTURE IN SRI LANKA AND PANAMA:

These are two selected contexts, the study of which facilitates a general understanding of earth architecture in hot-humid areas. Through a comparative analysis with Bangladesh, I seek to demonstrate the similarity in the techniques of earthen construction. As mentioned in section II.1, the architectural responses to climate in areas of low technological and economic levels is more direct, whereas, in more developed areas, the climate tends to be modified by mechanical means, and it is not the building which can be considered as a climatically responsive element. For this reason, I have chosen for comparison the two contexts, which also like Bangladesh, have low levels of economic and technological development, as well as hot-humid climates.

With regard to background and culture, Sri Lanka has many similarities with Bangladesh. Both cultures form part of the Indian sub-continent, and have a background of British colonial rule. Similarities exist between food habits, clothing, language, music and other aspects of culture. Hence it may be a reasonable argument that because of some similarities in culture, the indigenous architecture is also similar. For this reason, I have chosen the case of Panama, which is at a great geographical distance from Bangladesh, and has distinct cultural differences. Yet the similar hot-humid climate has produced earth architecture in Panama which is similar to that in Sri Lanka and Bangladesh.

It is important to note that I am not proposing a form of climatic determinism. Climate does not make the creation of certain kinds of architecture inevitable. Rather it makes it possible to create those kinds of architecture which are responsive to the environment (29). It is with this concept of the manifestation of architecture based on potential possibilities that I have embarked on the comparative analysis.

II.3.1. Sri Lanka:

There are three main forms of traditional earthen construction techniques in Sri Lanka:

1. Wattle and daub: This is the most widely used technique in traditional architecture in Sri Lanka. The availability of timber and bamboo, together with the clayey soil of the tropical island, has allowed this technique to be used extensively. Much of the wattle and daub architecture is in the coastal areas, where the heavy rainfall frequently washes away the earth, but does no great harm to the timber frame. For this reason, the buildings can be re-plastered and easily repaired.

This form of wattle and daub is however somewhat different from the prevalent wattle and daub technique in Bangladesh. The Bangladeshi technique of applying earth plaster on to woven bamboo mat walls does not exist in Sri Lanka. The "Ekra house" (30) construction technique in some regions of Bangladesh is similar to the Sri Lankan wattle and daub technique. In Sri Lanka, and also in the "Ekra house", the daubing is done by forming moist earth balls by hand, and then filling in the gaps between the wattle frame. However, the more prevalent bamboo mats in Bangladesh are plastered directed with the hand, using earth slurry.

These differences can be attributed to the highly developed bamboo technology in Bangladesh. There bamboo is treated as the primary building material and earth as the secondary one. But Sri Lanka lacks the highly developed bamboo technology of Bangladesh. Therefore, the

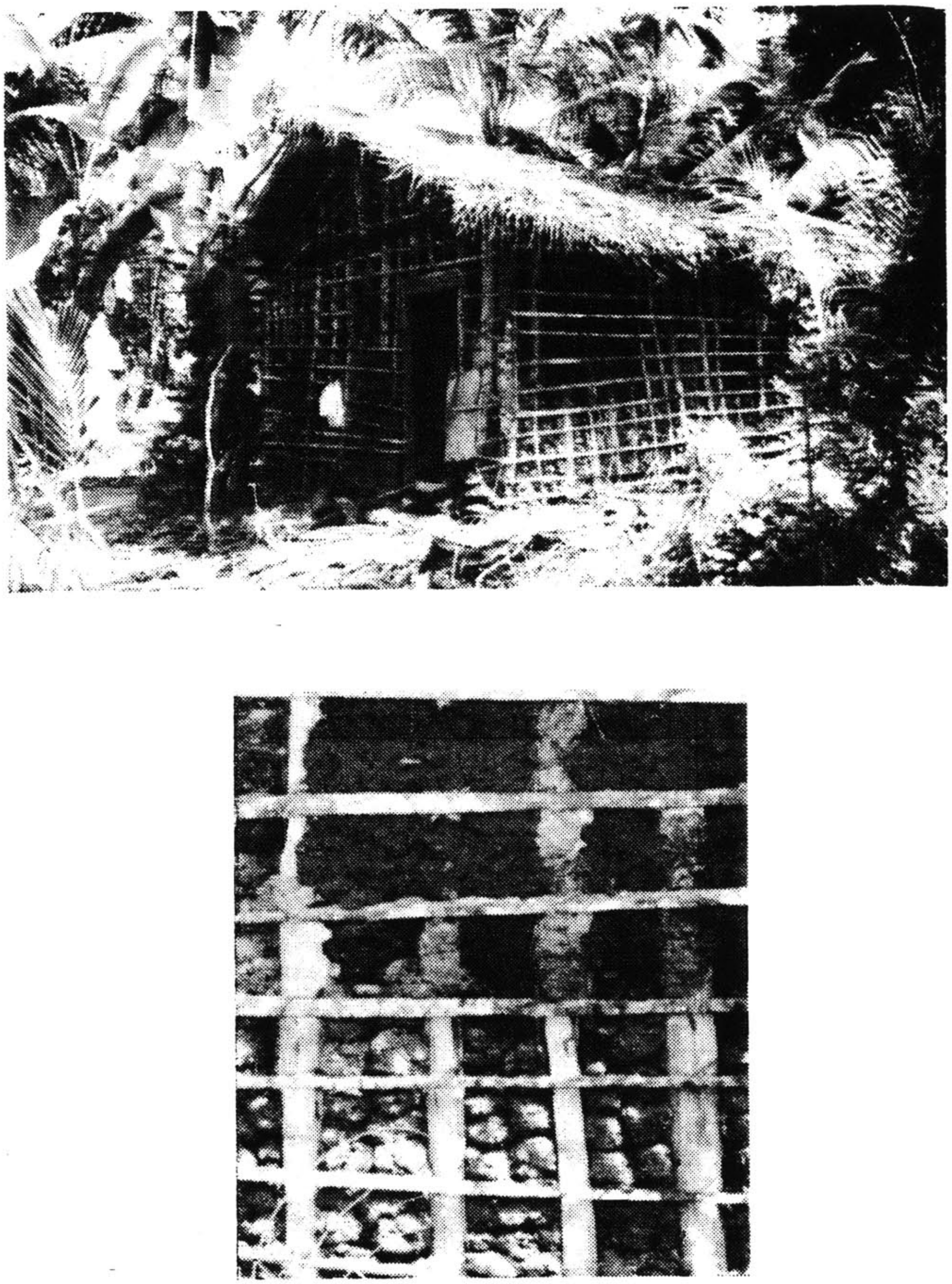


Fig. III.9. Wattle and daub construction in Sri Lanka.

timber/bamboo wattle is not of primary importance, rather it is earth which is the important material there.

2. Layering technique: This is very similar to the layering technique in Bangladesh, where the earthen walls are built in strata by hand, allowing each stratum to dry before the next is added. In Sri Lanka the system of rammed earth construction also exists, where earth is tamped and compacted inside wooden forms, and walls are also built in layers.

It is an interesting phenomenon that the layering technique has replaced the wattle and daub system in many areas where timber is scarce (31). This may be for two reasons. One may be that the wattle and daub system in Sri Lanka relies on certain kinds of timber which are not fast-growing, and not so much on bamboo, some species of which grow extremely fast. The depletion of local timber therefore prods building construction towards more "non-timber-intensive" methods. The other reason may be that the builders consider building in the layering technique relatively easier, for which reason it has grown in popularity, in some cases even more than the rammed earth technique. In any event, the emergence of the layering technique as a prevalent mode of construction indicates its viability in the context of Sri Lanka, and probably for the same reasons it is common in Bangladesh.

Fig. III.10. Rammed earth construction (above) and stacked sun-dried bricks (lower) in Sri Lanka.

3. Sun-dried bricks or adobe: This is also a prevalent mode of earthen construction in Sri Lanka. But like Bangladesh, it is more common in relatively drier areas which are at higher elevations as compared to coastal regions (32).

One important aspect of earthen construction in Sri Lanka is that earth is often combined with stone or rubble to build walls. This is a technique by itself, and I have not dealt with it here for the reason that stone is not an locally available building material in Bangladesh, and hence a description of this technique will not contribute much to the comparative analysis. However, it may be interesting to note that in traditional earthen construction in Sri Lanka, a "rubble in mud" (33) form of foundation is used. This indicates that in wet areas there is a need to protect the building from capillary rise of water from the ground. In Bangladesh such a practice is not common and consequently earthen walls unprotected from capillary rise of water are often damp and deteriorate rapidly. Ways to achieve protection from this capillary action have to be devised if improvement of the earthen architecture is to be implemented.

III.3.2. Panama:

In Panama there are two main prevalent modes of earthen construction :

1. Wattle and daub: This is quite common in most rural areas, but is not the most widespread earthen construction technique. It accounts for about 25% of the total of earth buildings (34). Here timber poles are used for the structural frame and reeds are woven to construct the wattle.

Wattle and daub buildings with thatch roofs are frequently nesting places for insects which spread the deadly "Chagas" disease. For this reason the local populace is moving away from this system of construction. In Bangladesh the same disease does not exist, but before applying this mode of construction there, it is necessary to investigate the possibility of dangerous vermin which may infest the building, and also ways of eradicating them.

2. Sun-dried brick or adobe: This is a widely prevalent mode of construction throughout all over Latin America, and in Panama accounts for the majority of the earthen buildings. Many innovative measures have been applied in this form of construction, among them the most well-known being stabilization of adobe with bitumen (35).

The widespread prevalence of this mode may not be a

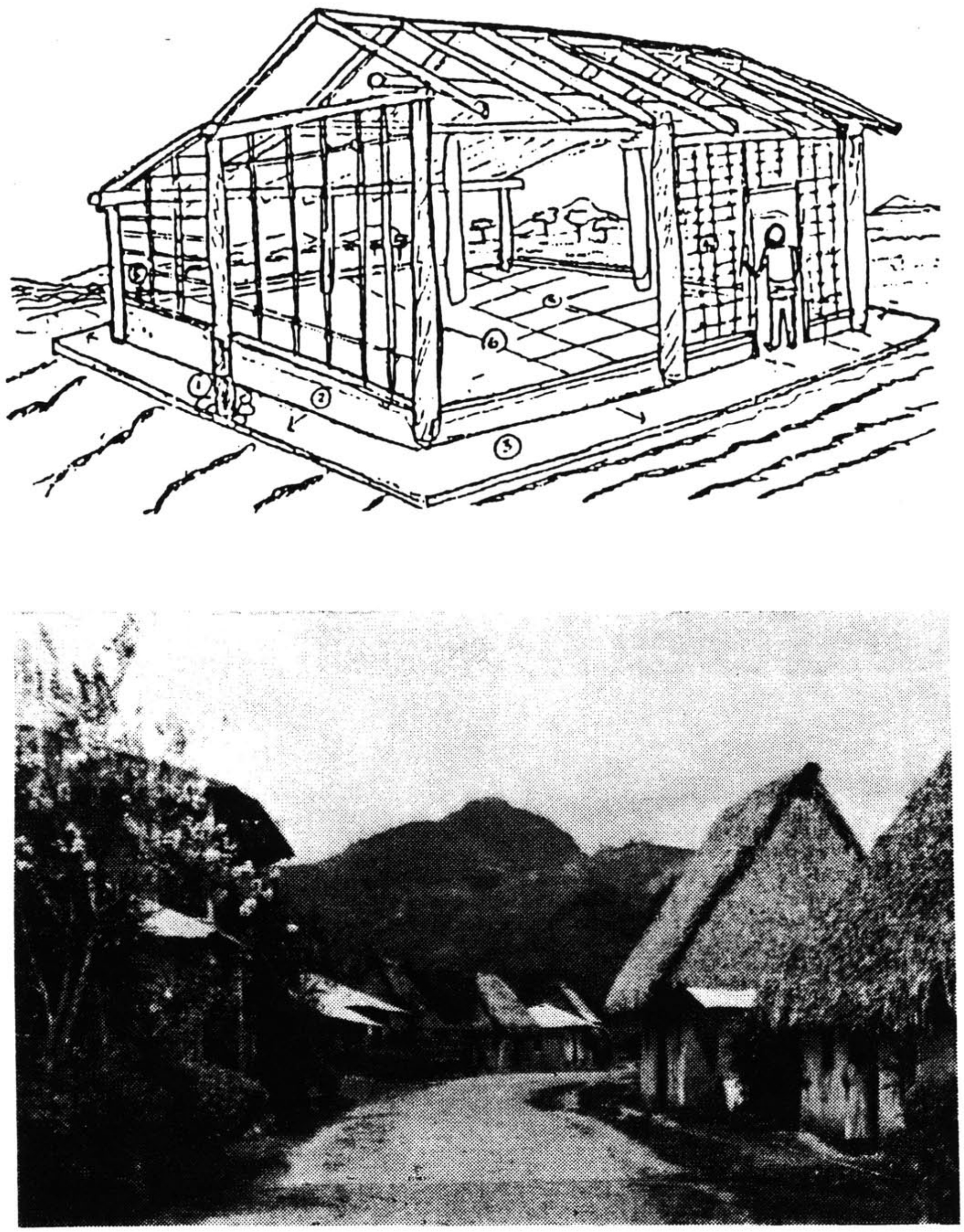


Fig. III.11. Wooden structure (above) of traditional wattle and daub construction (lower) in Panama.

Fig. III.12. Adobe houses in Panama.

climatic response, but rather a cultural one. The use of adobe was introduced by the Spanish colonizers in Latin America, who in turn had been introduced to it by the Moors (36). This system then became prevalent through the development of production systems and training of local builders. This, in a way, is similar to the introduction of sun-dried bricks by British colonizers in Bangladesh. However the prevalence of sun-dried bricks there is not as widespread as is in Panama, which may be due to a variety or combination of reasons.

The topography of the land in Panama is hilly and rocky, and mountainous in some regions (37). This could be one of the reasons for the development of adobe architecture because of the availability of high and dry ground for the production of adobe bricks.

The suitability of the natural soils, that is the necessary balance between sand and clay, may be another reason for the prevalence of adobe architecture in Panama. In general, sandy-clay soils are suitable for making adobe blocks. Unlike the alluvial clayey soil of the delta region in Bangladesh, the availability of sandy-clay soil in the predominantly mountainous regions in Panama could have prompted the widespread development of adobe architecture there.

As in Bangladesh, in both the contexts of Sri Lanka and Panama, there is the growing popularity of industrialized, imported building products like C.I. sheets and asbestos. The traditional, more natural ways of building are gradually being replaced by ways which are more dependant on technology and economic levels. Popular opinion perceives these methods as being more progressive and modern, and the national administrations also support that view. Whatever the cause of this transformation may be, the long term effects are often detrimental to the future environment, as well as involving a loss of identity for the cultures which are experiencing this transformation.

Change must come, the past cannot be encapsuled in a set time-frame. The old must inevitably make way for the new. But a change not rooted in the old order tends to be fragmented; in most such cases, redemption does not occur, instead often the new is fraught with uncertainty and alienation.

III.4. SUMMARY:

Climate is quite often one of the prime influencing factor of building form. This widespread notion has been contended by some, notable among them is Amos Rapaport who has suggested that in most cases, culture is the determining factor for building forms. However, it has been observed that the complex phenomenon of the development of building form is a composite product of various factors, and different factors play the major influencing role in different contexts. In a context like Bangladesh, the extremes of the climate and the lack of a remedial high technology has created architecture which is a response to the climate.

The architecture in most hot-humid areas have exhibited similarities in their responses to the climate, in terms of orientation, ventilation, floor levels and building materials. The case of Bangladesh demonstrates the typical response to the hot-humid climate.

Case studies of Sri Lanka and Panama have been selected to demonstrate the range of possibilities of the manifestation of earthen architecture in hot-humid regions. Several similarities exist between these cases and Bangladesh, but there also exist differences in the architecture because of various influencing factors, which are other than climate.

------------------------- NOTES ---------------------------

1. Paulo Soleri, "Use of Local Resources in the Marginal Lands", Arcosanti, an urban laboratory? (VTI Press, Santa Monica, Calif., 1987), p.21.

2. Amos Rapoport, House Form and Culture (Prentice-Hall, Inc., New Jersey, 1969), pp.18-45.

3. Ibid., p.83.

4. Ibid., pp.20-24.

5. See E.F. Schumacher, Small is Beautiful (Perennial Library, New York, 1973), and also, Ivan Illich, Celebration of awareness (Garden City, New York, 1970) and, Ivan Illich, Deschooling society (Harper and Row, New York, 1971). There are numerous contemporary writings on the subject from a variety of points of view. The references provided here represent some of the influential and well-known writings.

6. Alduous L. Huxley, Brave New World (Harper and Row, New York, 1946).

7. Rapoport, p.26.

8. Ibid., p.94.

9. Dewan Mahbub Hasan, "Building process of houses in rural Bangladesh" (Master of Engineering in Architecture thesis, Katholieke Universiteit Leuven, Belgium, 1987), p.31.

10. Hugo Navarro, "Earth construction technologies applied to the humid tropics", Architectural Institute of Japan, Report on the International Symposium on Earth Architecture (Beijing, China: n.p., 1986), p.214. Also see Rapoport, p.85.

11. Victor Olgay, Design with climate (Princeton University Press, New Jersey, 1963), p.90.

12. Dewan Mahbub Hasan, "A study of traditional house forms in rural Bangladesh" (Master of Architecture thesis, Bangladesh University of Engineering and Technology, Bangladesh, 1985), p.53.

13. B. Givoni, Man, Climate and Architecture (Applied Science Publishers Ltd., England, 1976), p.65.

14. O.H. Koenigsberger, T.G. Ingersoll, Alan Mayhew, S.V. Szokolay, Manual of tropical housing and building (Longman Inc., New York, 1973), p.216.

15. Anthony D. King, The Bungalow (Routledge and Kegan Paul, Boston, Mass., 1984), p.28.

16. Koenigsberger, et. al., p.219.

17. Hasan, "A study of traditional house forms in rural Bangladesh," p.77. Also photographic evidence supports the prevalence of the "false ceiling" in many areas.

18. Olgay, pp.91-92.

19. Koenigsberger, et. al., p.218.

20. Olgay, p.90, pp.166-171.

21. The evidence of the raised plinth as a characteristic feature of rural Bangladeshi architecture is supported by the writings of King and Hasan, as well as available photographic documentation.

22. Rapoport, p.94.

23. Koenigsberger, et. al., p.216.

24. There are various books on the vernacular architecture of South-east Asia, which show the prevalence of buildings raised on stilts in many parts of this area. For general reference, see Colin Duly, The Houses of Mankind (Blacker Calmann Cooper Ltd., London, 1979) and Paul Oliver, Dwellings: the house across the world (University of Texas Press, Austin, Texas, 1987).

25. Rapoport, p.94.

26. Koenigsberger, et. al., pp.219-220.

27. Some earthen houses built in the layering technique in Bangladesh, as discussed in the previous chapter, have a base of 26-30 inches (65-70 cm.), tapering to 19-22 inches (47-55 cm.), which is almost as thick as earthen walls in arid regions. However, this is not always the case. In many places, walls are also built by the layering technique and tapered to lesser thickness, in order to prevent thermal time lag.

28. See chapter II, section II.3.2.

29. This concept is similar to Rapoport´s, "house form is the result of choice among existing possibilities - the greater the number of possibilities, the greater the choice - but there is never any inevitability, because man can live in many kinds of structures" (p.59). This notion certainly frees vernacular architecture from the general perception that it is a direct result of inevitable climatic adaptation.

30. For a description of the "Ekra house" see chapter II, section II.3.2. and chapter V, section V.2.2.

31. B.D. Nandadeva, "Traditions and techniques of earthen architecture of Sri Lanka", Getty Institute for Conservation, Proceedings of the 6th International Conference on the Conservation of Earthen Architecture (Adobe 90 Preprints) (Las Cruces, New Mexico: n.p., 1990),

p.108.

32. U.K., Overseas Development Administration, David G. Robson, Aided Self- Help housing in Sri Lanka 1977 to 1982, p.86. Information has been provided here on the regions where sun-dried brick construction is common, which mostly are areas somewhat elevated from sea-level.

33. Ibid., p.90. Also see Nandadeva, Adobe 90 Preprints, p.106,108.

34. Navarro, International Symposium on Earth Architecture, p.213.

35. R.J.S. Spence and D.J. Cook, Building Materials in Developing Countries (John Wiley & Sons Ltd., New York, 1983), pp.59-60.

36. Jean-Louis Bourgeois, Carolee Pelos and Basil Davidson, Spectacular Vernacular (Aperture Foundation, Inc., New York, 1989), p.56. Information on the etymology of the word "adobe" has been provided here.

37. For general topography, climate and other salient features of Panama, see U.S. Government, Secretary of the Army, Richard F. Nyrop, Panama, a country study, 1981.

CHAPTER IV

"Water is in the jar but we go around thirsty, the sweetheart is in the house but we search for one around the world." (1)

CHAPTER IV. INNOVATION AND APPLICABILITY

In this chapter, I will review some selected innovative construction techniques which use earth in non-traditional ways with the aim of improving its strength and durability. While there is a variety of such innovative techniques, I have selected some of the major ones, and grouped them into four main categories. I will discuss each category according to the possibility of its application in the context of rural Bangladesh. It should be mentioned here that all these techniques have been developed principally with the intention of retarding the deterioration of earthen structures by water and moisture.

IV.1. COMPACTION:

This technique consists of mechanical methods for compacting earth to increase the density of its mass. It has two main results in terms of improving the quality of earth for building purposes. One is that it increases the strength of the earth, and the second is that compaction reduces the air gaps in the earth mass, thereby restricting the penetration of water (2). The increase in strength depends on the moisture content of the soil. If the earth is either too dry or too wet it may be very difficult to compact. For every type of soil, there is an optimal moisture content required for effective compaction.

There are two main types of building products that can be produced by compacting earth. I will discuss them in the following sections.

IV.1.1. Rammed earth:

Traditionally this technique has been used to build floors, walls and in some cases roofs, in different parts of the world. Wooden formwork is generally used for constructing rammed earth walls. In the south-west region of the United States, highly sophisticated and efficient ways of constructing rammed earth walls have been devised (3). These methods will not be considered applicable in the context of this thesis, as they tend to require a high level of technical development for their implementation. Simpler, yet revised methods of building rammed earth walls, such as those which have been prevalent in southern Morocco (4), may have limited applicability in rural Bangladesh, but they involve the application of a completely new technology with which the local builders are totally unfamiliar. The merits of this system may be undermined by the high costs of production and training.

However, according to King (5), the system of building layered earth walls exists in Bengal. This system is

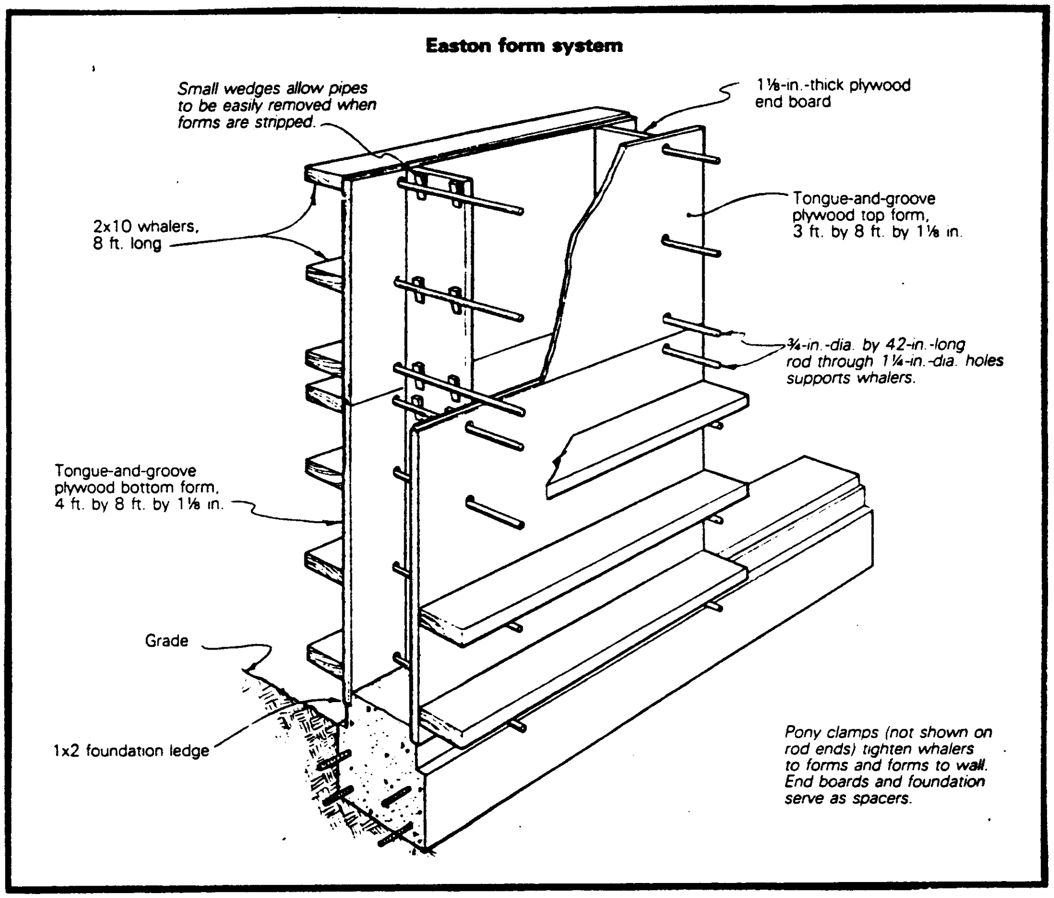
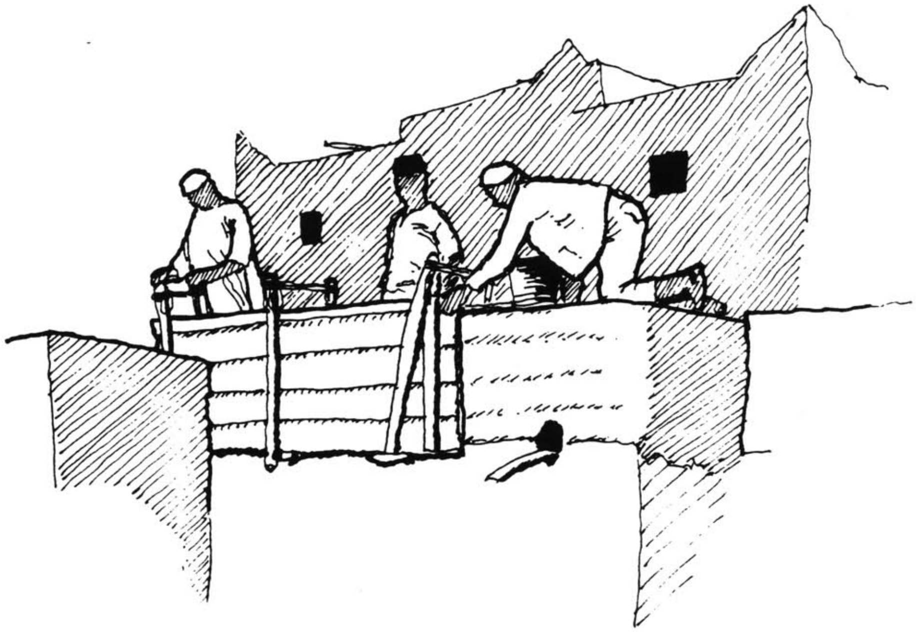


Fig. IV.1. A highly sophisticated system for constructing rammed earth buildings in the southwestern U.S.A.



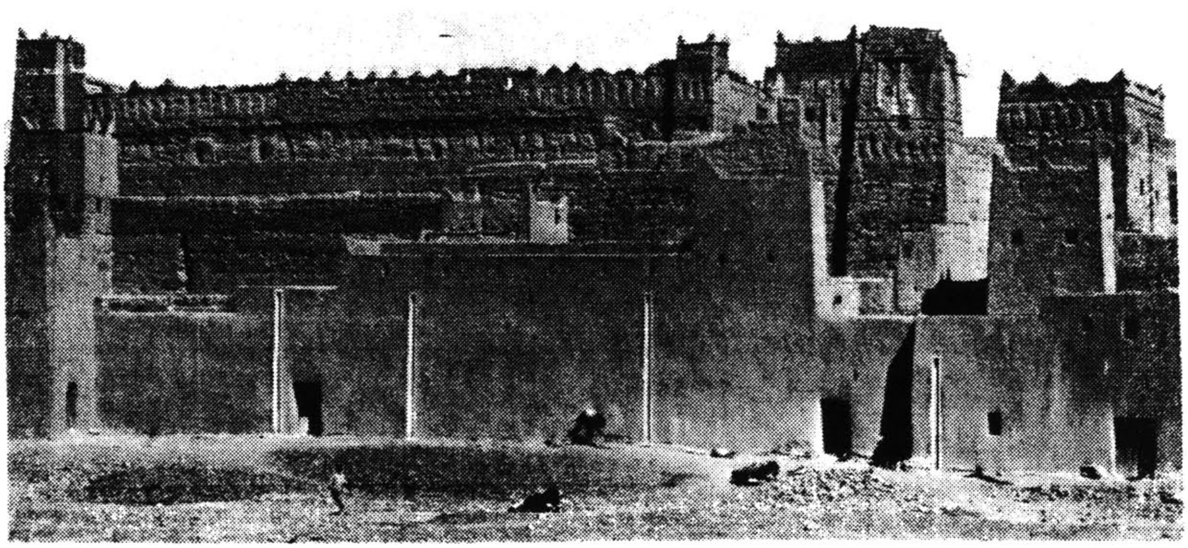


Fig. IV.2. Traditional rammed earth construction in Morocco.

similar in some ways to the construction of rammed earth walls. No formwork is used, but the earth is compacted to some extent by hand. Like proper rammed earth walls, walls built in this method are constructed one layer at a time, each layer being allowed to dry before the next is applied. While this method has applicability in the northern parts of Bangladesh - which is drier and less prone to cyclonic weather - in the stormy regions of the delta and coastal areas of the south, the low tensile strength of the structures built in this method makes it subject to rapid climatic decline. King's accounts of Bengali rural dwellings relate to the Dinajpur district in northern Bangladesh.

Rammed earth walls are usually thick as they have been conventionally built in arid regions, where they have been adapted to the diurnal temperature variation. In humid areas like Bangladesh, where the daily variation in temperature is not as great as in arid areas, the need for thick walls does not exist. For such humid climates, according to Koenigsberger,

> "It is, in fact, advisable to construct buildings of low thermal capacity materials, using lightweight materials." (6)

The minimum thickness of rammed earth walls is preferably 16 inch. (40 cm.), although thinner stabilized rammed earth walls of 12 inch. (30 cm.) thickness can be built with considerable difficulty (7). This, in general, is too thick to be comfortable in humid areas. Thinner walls than that are required for the climate of Bangladesh, so that the buildings can respond rapidly to short duration thermal events, and an suitable response would be to search for solutions that satisfy that criteria. Earthen walls built in the layering technique in Bangladesh are often quite thick, but as mentioned earlier, this is evidenced in the drier and less humid areas. In those areas, the construction of rammed earth walls might be applicable to some extent.

IV.1.2. Earth blocks:

There are two main types of earth blocks for use in masonry construction:

a. "CINVA-Ram" or pressed earth blocks: These have been claimed to possess great strength, especially by stabilization with cement. In "Shelter" (8), description of the superiority of the pressed blocks, along with the price and description of the press has been provided. Various other sources also recommend the pressed blocks for a durable construction.

However, the use of pressed earth blocks would entail the introduction of a new product, and the training and installation of production facilities associated with it. The price of a single "Cinva-ram" press was U.S.$ 175 in

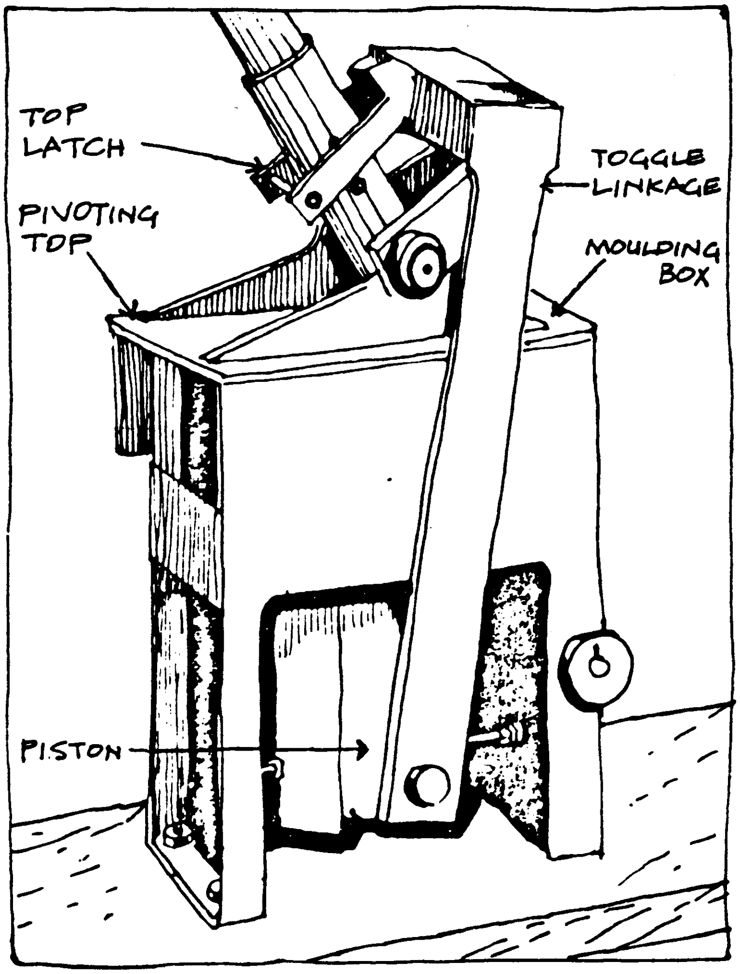


Fig. IV.3. The CINVA-Ram for making compacted earth blocks.

1973 (9). At current price, that would mean an expenditure per machine of more than $1000. Such an expensive machine would have limited use in a poor country like Bangladesh, unless major institutional changes come about which will provide incentive for the development of production and distribution facilities. According to Spence and Cook,

> "it seems to have been successful mainly when used in the context of highly organized self-help housing schemes with a considerable external technical input." (10)

I have worked on a project in Auroville, India which used the "CINVA-Ram" process. It was too expensive for large-scale and widespread use, and hence had little potential for replicability.

Several CINVA-Ram houses had been built by the organization CARE in Bangladesh in the early 1970s. M.P. Chrisholm has narrated the inappropriateness of this form of construction in Bangladesh:

> "In one area a Bengali Government official that after the CARE CINVA-Ram housing programme and workers had finished and moved to another locality, one local recipient family of what was a very well constructed house, costing 2,200 taka (1972) proceeded to carefully remove all the C.I. sheets from the roof, painstakingly dismantled the CINVA-Ram blocks and took them into the local bazaar. With the income from the sale of the C.I. sheets, and from the blocks, they re-erected a traditional bamboo/thatch house, bought two cows and a plough." (11)

It is clear from this incidence that CINVA-Ram block construction is too expensive for the rural poor of Bangladesh. Its introduction is inappropriate in a socio-economic context where market dynamics prevent the use of the blocks by the target low income group. It certainly may have some potential application in the case of affluent residences and institutional buildings. However, even in the case of such application, it has to be evaluated in comparison to local fired brick construction, which is an established practice in many parts of Bangladesh.

Another fact needs to be mentioned here. As the system of construction with blocks requires mortar joints, the joints often tend to be the vulnerable points subject to deterioration by moisture, especially in the case where mud-mortar is used. Stabilization of the mortar has been attempted in some projects, but effective bonding occurs only when the blocks are also stabilized.

In some projects, such as the one mentioned above in Auroville, India, earth block walls had been plastered with cement, with the objective of protection from water. Protruding pieces of stone chips were embedded into the mud mortar joints, in order to improve bonding with the mud plaster. In some cases, the earth block walls are covered with a screen of wire mesh to ensure effective bonding, and also to increase the flexural strength and stiffness of the cement plaster and to control cracking due to thermal expansion and moisture related shrinkage. Such a practice is common in the south west of the U.S. (12), and also in Latin American countries, such as in Guatemala (13). In the latter case, the wire mesh has larger gaps, and consequently

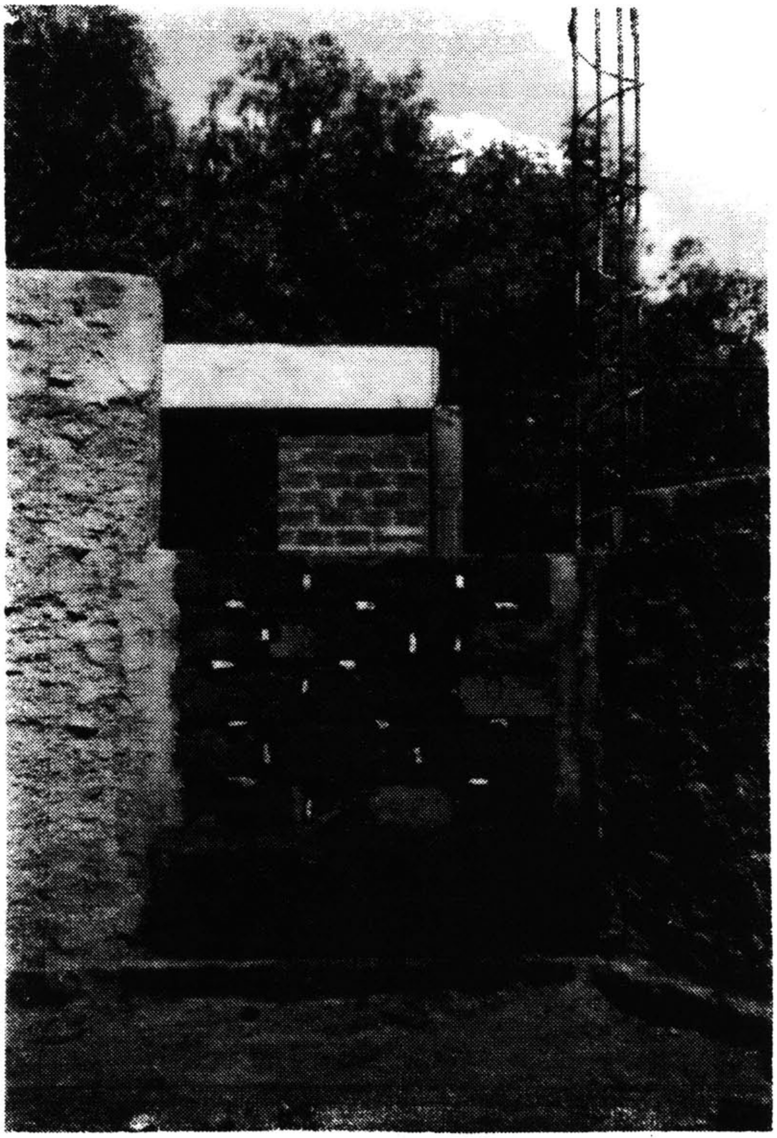


Fig. IV.4. Earth-block wall in Auroville, India, with protuding pieces of stone chips to provide bonding with the cement plaster to be applied.

cannot bind the cement plaster well, thus it peels and falls off easily.

But in both systems, the actual bonding occurs between the stone chips or wire mesh and the plaster, and not so much between the earth blocks and the plaster. Thus, the interface between the earth wall and the plaster remain vulnerable. The earth blocks have to be cured for a long time in order to get rid of all the internal moisture content before they can be plastered, otherwise the moisture gets trapped by the plaster and greatly weakens the wall. In arid regions like the south west of the U.S., plastering is done not to provide water protection, but as a decorative surface applique (14). It often works to a large extent, as the internal moisture content is very low. However, as has been observed by architect James W. Garrison in Arizona,

> "Cracks, caused by the difference in expansion coefficients between concrete and adobe," (15)

results in the plaster peeling off and collapsing from the surface of the wall. And in wet regions, the added effect of internal moisture attack, such as in Guatemala, makes this a totally ineffective system. The use of cement in earthen construction, other than for stabilization as I will discuss later, cannot be for surface coating, as these two materials are mutually incompatible and never form strong bonds.

In the case of cement stabilized earth blocks, if the mortar is composed of the same constituents as of the block,

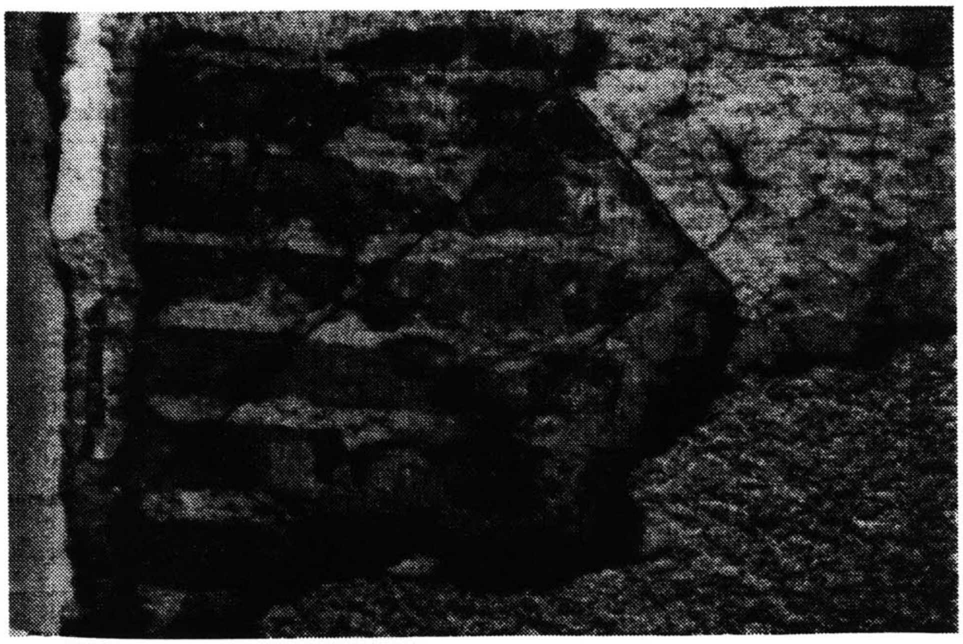


Fig. IV.5. Earthen wall in Guatemala, where the cement plaster has fallen off. Note the wire net under the plaster which does not achieve bonding.

but of a weaker consistency, and then plastered with soil-cement plaster of the same consistency as the mortar, the result may be durable structure. In this case, effective bonding occurs between the blocks, mortar and plaster. But this is more so for uncompacted blocks, like sun-dried bricks, than for compacted blocks, because the compacted nature of the blocks is very different from the uncompacted mortar and plaster. Pure cement plaster on stabilized blocks does not work as well, even though the cement in the block tends to form bonds with the cement plaster. As will be discussed later at the end of this section on Stabilization, cement is an extremely scarce and expensive commodity in rural Bangladesh, and therefore it may not be a suitable notion to advocate its use on an extensive basis, especially when locally available materials can fulfill the demands for its need.

Of course, other means of surface protection of earth block walls can be devised, but this is not the real issue here. The primary concern is to search for an appropriate building system for rural Bangladesh which is based on traditional techniques and is feasible, and earth block construction offers neither of these.

b. Sun-dried bricks or adobe: This is not really a method of compaction, but I have included it here to provide a comparative analysis between the two main types of masonry construction with earth.

Before British colonial rule, the use of sun-dried bricks ~~was~~ limited to institutional buildings and was not used for domestic architecture in Bengal. Several mosques, notably the Shaitgumbaz Mosque in Bagerhat, and also Hindu temples, such as the Vishnupur temple complex in West Bengal, made extensive use of sun-dried bricks laid in pozzolanic lime mortar. The exterior surface of these buildings employed low-fired or bisque-fired bricks, and terracotta panels for cladding. However, these buildings were all completed prior to the 15th century.(16) The use of the "superior" material, sun-dried bricks and terracotta, is thought to have indicated monumental or institutional significance.

With the advent of British rule, the administrators found the local dwelling mode consisting of houses made of earth and bamboo unsuitable in their eyes for habitation. This gave rise to the colonial "bungalow", made of sun-dried bricks. Anthony King has provided a detailed account of the development of the "bungalow". According to him, by the 19th century there were two types of bungalows,

> "native bungalows are generally built of wood, bamboo etc. but those erected by Europeans are generally built of sun-dried bricks and thatched or tiled." (17)

The production of sun-dried bricks is an established practice now, but their use is limited. Most sun-dried bricks are eventually fired or used for temporary

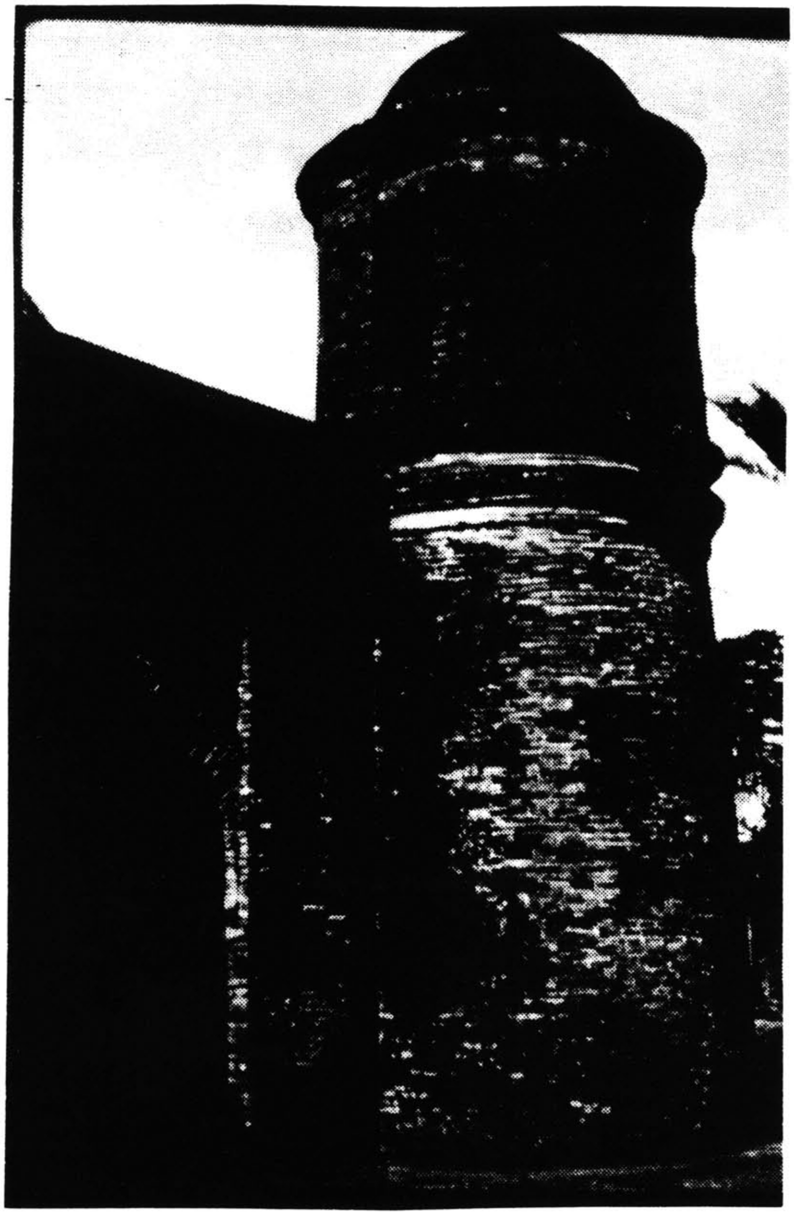


Fig. IV.6. Shaitgumbaz mosque in Bangladesh - the early use of sun-dried and bisque-fired bricks.

structures. Nevertheless, with the addition of stabilizing agents durable sun-dried bricks may be produced within the framework of the existing production facilities. As mentioned before, there is the possibility of obtaining stronger bonds, and therefore a more durable structure. Sun-dried bricks may be used in conjunction with lime-pozzolanic mortar, where lime is an available resource in Bangladesh; this process may be deemed as an appropriate response to local architectural needs. As mentioned before, this combination offers the possibility of walls with stronger bonding, and hence a more durable structure. If lime mortar is used, with a proportion of burnt clay powder added to it, in the ratio lime:pozzolan = 5:1, (18) pozzolanic reactions occur over time, between the lime and sun-dried bricks, creating extremely durable bonds.

Sun-dried bricks may be used to some extent in institutional buildings, as had been done in pre-colonial times. They may serve well for the construction of interior partition walls, where they are well-protected from rain, their production being less energy intensive than fired bricks. With the utilization of water protection techniques, such as broad roof eaves, sun-dried brick construction offers the possibility of a viable architectural solution for external walls. Other techniques of protection against rain are discussed later.

An important consideration regarding earthen construction needs to be mentioned at this point. Socio-cultural and technical factors certainly have a powerful bearing on the choice of technology, but in the case of building with earth a fundamental factor is the type of soil available, as this often dictates the technique to be chosen. Magnus Berglund has built a number of earthen houses both in the arid region of the American southwest and the humid regions of Mexico. An important observation provided by him is,

> "while a sandy-clay soil will make good rammed earth and adobe, a soil heavy in clay is best for adobe only. The problem with clayey soil is that it shrinks as it dries, and any wall that is monolithically built with it will be subject to serious cracking. If you use individual bricks of the same clayey soil, however, each brick will do its shrinking before its laid into the wall. So a good rammed earth soil will also make good adobes, but a soil that makes good adobes won´t necessarily make good rammed earth unless it is stabilized." (19)

Therefore it is a must to conduct soils analysis in Bangladesh before building with earth there. But laboratory facilities for conducting soil testing are limited; they are mainly available in the few urban areas. There are a variety of simple field tests to determine the clay and sand contents of the soil, the primary criteria for the choice of technique. Magnus Berglund has listed some of the major field tests to be conducted before building earthen buildings, such as the mason-jar test, thread test, squeeze-the-mud-ball-test and even methods of visual inspection, smelling and tasting soil.(20) While these are extremely useful and often well known principles to the best of most local builders, in some circumstances it may be useful, if possible, to conduct laboratory tests specially to determine the bearing capacity of soils and for their mineral and organic contents. In some cases, it may be fruitful to rely on the judgement of experienced local builders who have an understanding of local conditions. The advice of experienced local potters about soil may also be sought in some cases. At the same time, caution is to be exerted so as not to rely completely on local expertise, but also to refer to pertinent experiences elsewhere, and when possible, to utilize scientific expertise.

This thesis is based on the notion of developing building techniques which can be applied by the rural populace of Bangladesh without incurring undue cost, high-tech operations and complex procedures. Local materials are to be used in simple innovative ways so that they can be easily applied without continual technical supervision and assistance. Therefore, the wisdom of the best of local builders are to be utilized whenever possible, to obviate expensive laboratory tests and external technical assistance.

Studies in soil mechanics provide information on the nature of soils in alluvial deposits in humid flood plains, which is the context of Bangladesh. Such soils have been characterized as being composed mainly of silty, clayey

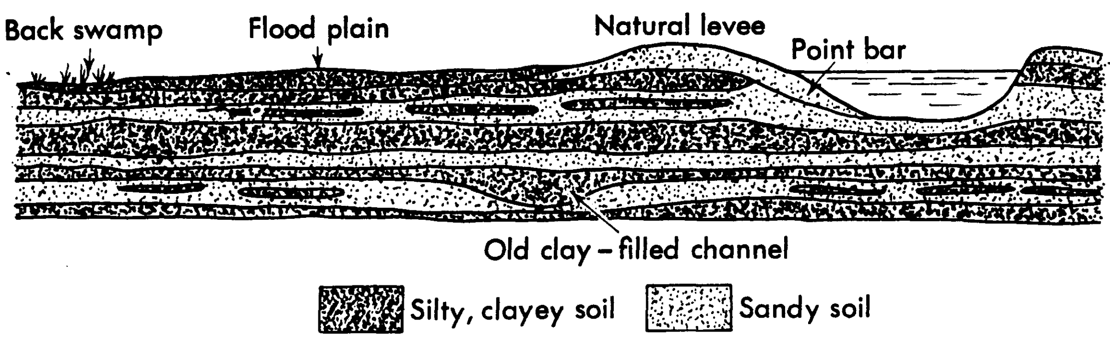


Fig. IV.7. Cross-section of flood-plain alluvial deposits in a humid region, showing the prevalence of clayey soil.

ingredients (21). As described before, such soils are suitable for adobe construction, but not for compaction without stabilization. Which is another reason for selecting sun-dried brick construction as one of the viable modes of earthen construction. In the discussion on stabilization at the end of this chapter, I will return to this theme.

IV.2. FIRING:

Firing earthen buildings is a relatively new technique developed by architect Nader Khalili (22). The basic concept is to build a structure with earth, then seal up all openings and fire the entire structure from within, much like a conventional kiln. By the process of firing, the structure is converted to ceramic form and hence becomes stronger and more durable. Application of glazing agents on the surface of the structure can impart a water repellant quality, much like a piece of glazed ceramic pottery.

Firing is a new building system and has not been perfected yet. Much research and development has to be conducted to improve this system. Yet, the system has the potential of producing completely impervious surfaces using earth as the basic building material, incurring no damage from rain or moisture. Such a system, once perfected would be capable of producing the ideal building for the wet

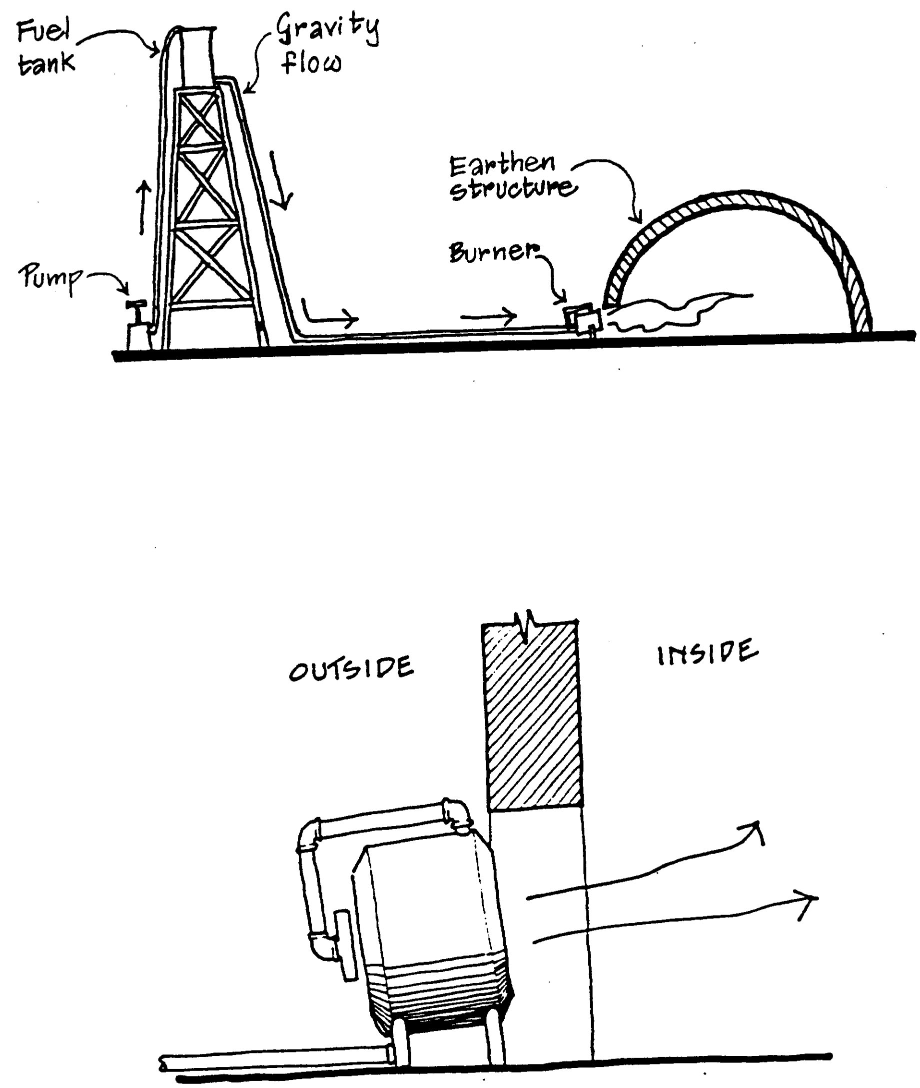


Fig. IV.8. Firing an earthen building with burners.

climate of Bangladesh.

On the other hand, empirical evidence demonstrates that the majority of ceramic structures have been built in developed countries, with the exception of Nader Khalili's work in Javadabad, Iran, and Ray Meeker's work in Auroville, India (23). During his presentation to students at M.I.T. in October, 1990, Ray Meeker stated that fired earth structures proved to be expensive for the context of India, and unless major institutional changes are brought about and the building system is perfected, it is neither cost effective nor energy efficient. A considerable part of the building system depends on mechanical gadgets, such as burners, thermocouples etc. to which most less developed countries have limited access. This system requires a very high amount of fuel, to which most less developed countries also have limited access.

Khalili has argued that by loading the inside of the structure with earthen products like unfired bricks, tiles, pottery and even sanitary fixtures, the firing process can prove to be cost effective.

> " every time we fire a building we can bake brick, tile, pottery, and ceramic products with it; sell the products and pay for the house. The dream of making no-cost housing instead of low-cost housing with earth architecture could become a reality." (24)

Two important issues come into focus in this regard. The first one, as noted by Ray Meeker, is that there were serious problems in marketing the fired products. They were

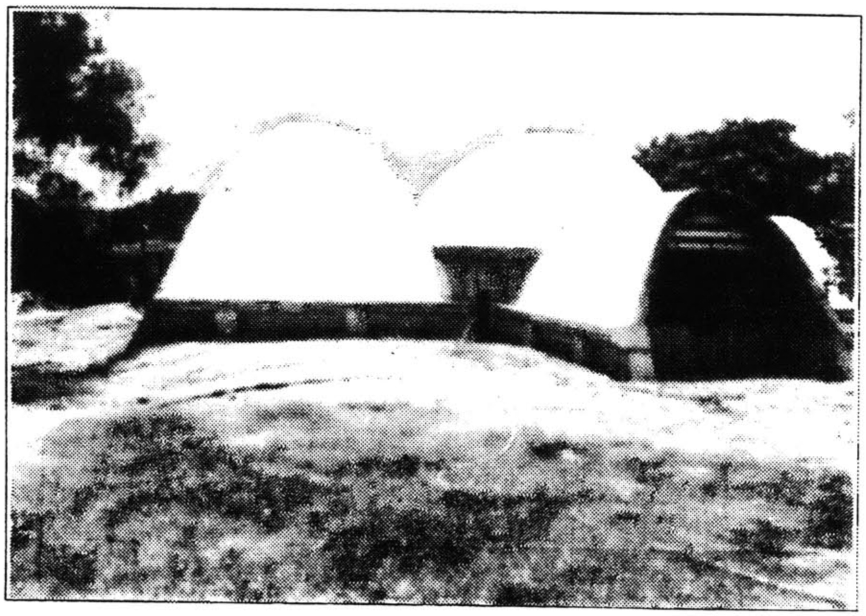


Fig. IV.9. Ray Meeker´s fired house in India.

unable to withstand competition with existing industries producing such products in terms of the marketing price and profit margin, as well as quality. Existing industries with government subsidies, as well as larger scale production facilities were capable of producing products which were cheaper and better in quality. Unless major institutional changes are sought as a pre-requisite for the production and marketing of such products, attempts to fulfill Khalili´s "dream" will be met by failure.

The other issue is that in order to make the production of fired structures a socially pragmatic enterprise, a community involved in the process has to be developed. Which consists of the training of local builders in this unfamiliar method of building, production of energy sources (25), production of ceramic products and other such activities related by the creation of a community. Ray Meeker´s work in India is attempting to develop such a community, in this case a potter´s community.

The potential for developing such a community within rural Bangladeshi society has to be investigated prior to establishing the fired earth system as a rural building type. Otherwise, except for a few isolated experimental structures, the notion seems unlikely to be realized as an acceptable building mode.

The application of the firing technique can only be achieved in a semi-rural or urban-peripheral context. In order to market the fired products, urban transportation links and distribution facilities are required. On the other hand, the firing operation may pose fire hazards in urban neighborhoods, which tend to be denser developments than rural neighborhoods. Having such location specific application diminishes the potential for a widespread utilization of the technique.

Of course, being a new and unfamiliar building system, considerable training to local builders have to be imparted, which may not be feasible in the long run. According to Turner, this would be termed as a "high technology method" (26), for which most less developed countries are not prepared. Turner has proposed a "Partially-industrialized Intermediate Technology" for most less developed countries (27), and the system of fired earth structures is certainly not one. Turner has proposed a "Partially-industrialized Intermediate Technology" for most less developed countries (27), and the system of fired earth structures is certainly not one. In spite of attempts to incorporate traditional building techniques, the process of firing is simply too sophisticated to be even deemed as "partially-industrialized".

It is important to introduce one further issue at this stage. For firing, the structure needs to be sealed and this necessitates the construction of structures with roofs which will also be fired. Only domed or vaulted roofs satisfy this requirement. But nowhere in the history of Bangladeshi domestic architecture have domed or vaulted roofs been used. Hence, the introduction of these forms for residential buildings may be considered culturally incongruous and by the local populace as an imposition, which may prove to be a severe impediment to its acceptability. However, there is a precedent for the use of domed roofs in institutional buildings, such as mosques, in Bangladesh, and therefore in some cases the firing technique can be considered without introducing culturally alien forms.

As mentioned earlier, this relatively new building system has not been technically perfected. Several technical issues have not been resolved yet. Some of these may be resolved through further research and development, but some may indeed prove to be insurmountable obstacles to the development and application of the system. I will outline some of the major technical problems:

a. It is extremely difficult, if not impossible to achieve uniform firing of the entire structure, especially in the case of large volumes. Small structures fired with wood and with continuous stoking may result in a relatively uniform firing, but structures larger than 100 square feet require so much fuel that it ends up being a tremendously expensive and energy intensive operation for producing structures with non-uniformly fired walls. Burners designed by Khalili (28) are worse in this respect, as they concentrate flames only in certain parts of the structure, and in order to obtain some degree of uniformity in firing, they have to be supplemented by timber fuel and stoking. In the case of a small pottery piece fired in a kiln, the volume of heat is large enough to envelope the piece from all sides and fire it completely and uniformly. But this is not the case when firing entire buildings. The amount of heat required to fire a building is as large in the same proportion as the building is larger than the piece of pottery.

Khalili compares the earthen buildings to be fired to Iranian brick kilns:

> "To build a house out of earth, then fire and bake it in place, fuse it like a giant hollow rock.
> The house becoming a kiln, or the kiln becoming a house."(29)

The idea of firing earthen structures was derived from earthen brick kilns which due to repeated firing get transformed into ceramic form (30). Daniel Rhodes, a ceramist, has observed that uneven temperature inside the kiln is a source of problems for most potters (31). It is this problem of uneven temperature which is responsible for the non-uniformly fired earthen structures. While the uneven temperature inside the kiln is an obstacle to successful firing of pottery pieces, through repeated firing the kiln eventually gets completely and uniformly fired. But the process of firing buildings is done only once and the uneven temperature cannot produce a sturdy building. If a building could be fired many times, then like a kiln it would eventually be transformed completely into ceramic form. This, however, is not possible and it may be a impossibly difficult problem to find a way to fire a structure uniformly.

b. The art of pottery provides us with the evidence that large pieces are difficult to fire without cracks, which often fail the piece. Daniel Rhodes has written extensively about this phenomenon. According to him,

> "Before they are fired, objects made from clay have a low tensile strength. The stresses which always accompany drying shrinkage often cause cracking, especially in large objects or in those which are complex in shape." (32)

These stresses, often termed as residual stresses, are also present in the case of earthen structures, where cracks appear after the structure has dried and undergone shrinkage. But these cracks are usually small and can easily be rectified later. However, when the structures are fired, rapid shrinkage occurs and the cracks get enlarged, and in some cases may considerably weaken the stability and strength of the structures. The addition of fibrous material, such as straw, to the earth mixture may reduce the stresses by providing the necessary tensile strength. In the case of unfired earthen structures, this procedure is indeed effective. But when the structures are fired, the fibrous materials burn out and leave voids within the structures. For small pieces of pottery, these voids are negligible, as has been noted by Daniel Rhodes (33), but in the large fired structures, these voids may seriously weaken the structures. Rhodes has devised the method of reinforcing with glass fibers, which do not burn out due to firing but form a strong matrix inside the fired pottery. While this method has advantages for making large pieces of pottery, its use in firing buildings would entail a very large amount of glass fibers. Glass fibers being an industrial product and Bangladesh being a country with a very low level of industrial development, the supply of glass fibers would have to be imported and hence would increase costs, and create barriers to access to the buildings for the majority of the rural population. Besides that, the use of glass would reduce the potential of the earth to be re-used after the lifetime of the building has been expended. Such recycling potentials are extremely important in a country with low resources like Bangladesh, and ways to realize those potentials must be considered before any new building product is introduced.

c. In order to build a completely water repellent fired structure, it has to be glazed inside as well as outside. Up until the present, no structure that has been fired has been glazed successfully on the exterior surface. So far only in one project, which was the dome in New Cuyama, California, glazing on the external surface was attempted with no success at all (34). In order to vitrify glazes a high temperature of about 2000 degrees Fahrenheit is required. A much higher temperature has to be achieved inside the structure, for it to penetrate the wall thickness of the structure to its external surface and vitrify the glaze on it. Possibly with a very large amount of fuel and a prolonged period of firing, glazing may be obtained on the external surface, but this would be far too expensive to and too elaborate an operation to be applied in Bangladesh.

As has been noted above, firing large earthen buildings cannot result in a uniformly fired structure. This is also a problem with glazing; uneven temperature creates unevenly glazed surfaces, where the unglazed surfaces are vulnerable to moisture attack.

In spite of all the disadvantages, fired earth structures do have the potential for application in less developed countries, specially in those with wet climates. This potential should not be overlooked completely. With its resources, the developed world offers the possibility of further research in this area to improve the system to eventually make it feasible for less developed countries. Research in developed countries may require high investments initially, but may prove to be cost effective in the long

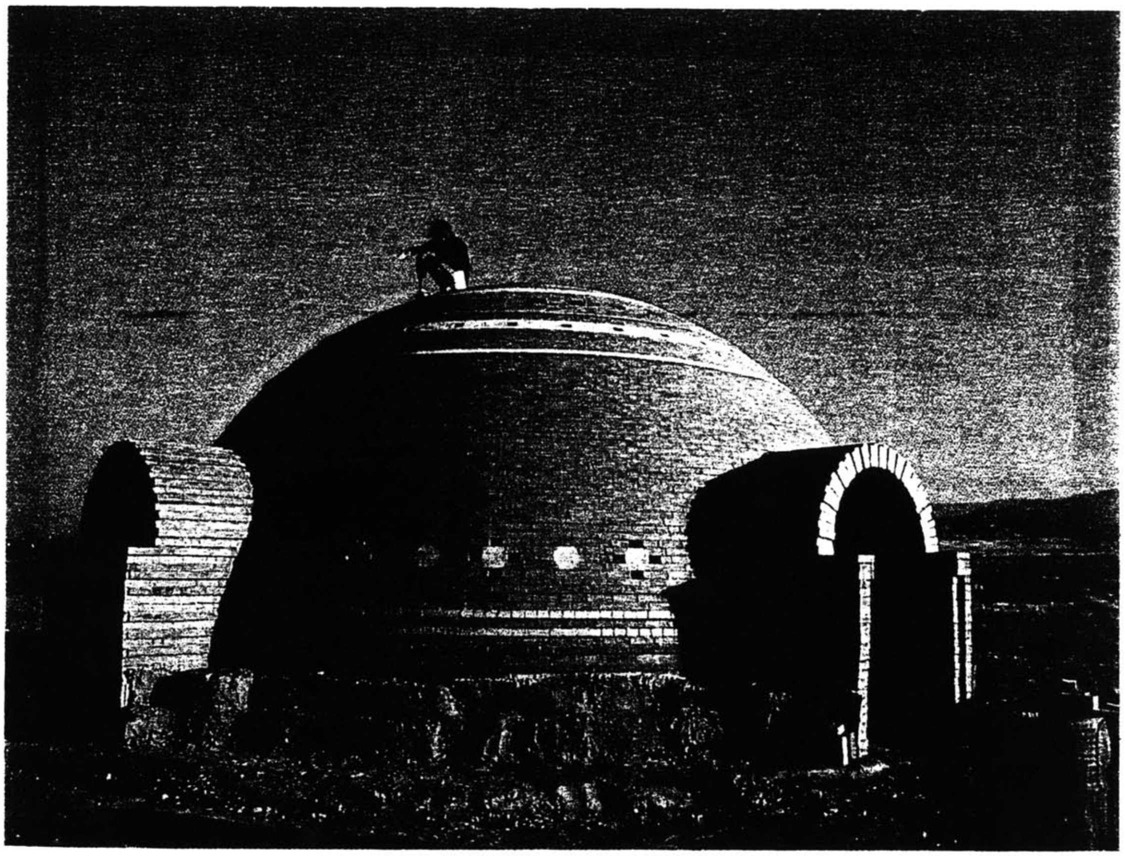


Fig. IV.10. Dome in California, U.S.A., prior to firing. This structure was fired continuously for 72 hours, yet did not yield satisfactory results.

run, especially if the drawbacks of the system are overcome and thereby can be applied on a widespread basis.

IV.3. CHEMICAL TREATMENT:

In recent years, ways to treat earthen structures with chemicals to increase their durability have been developed. The primary objective of developing such techniques was for the preservation of historical earthen structures, but they were also developed with the intent of application in new construction with earth. The work of the Getty Institute for Conservation in this area is notable (35).

The initial experiments consisted simply of applying a layer of acrylic coating on the surface of earthen structures. This was believed to impart a water repellant quality, as water would be unable to penetrate the acrylic coating. In some cases, a coating of bitumen was used instead of acrylic with the same notion that covering an earthen structure with a water-proof material would protect it from deterioration. But this technique had the same problem as in the case of plastering with cement. No permanent bonding between the surface coating and earth would occur and thus the interface would remain susceptible to deterioration from internal moisture condensation and differentials in the coefficients of expansion. The acrylic coating would eventually peel and fall off. In the case of

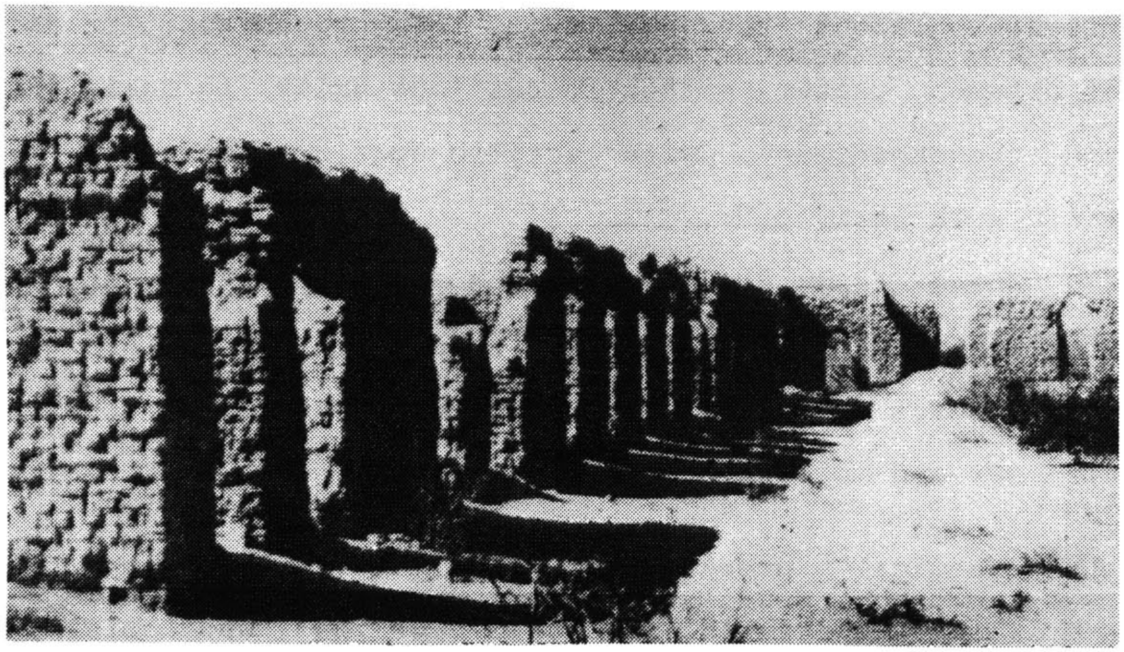


Fig. IV.11. Fort Selden ruins, New Mexico, U.S.A. Site for experiments with chemical consolidants by the Getty Institute for Conservation.

bitumen the adhesion was better, and in spite of not forming a permanent bond, it would endure longer than acrylic coating. But eventually the bitumen coating would also peel off and regular maintenance is required in order to sustain the protective quality of the coating. In the 6th International Conference on the Conservation of Earthen Architecture in New Mexico, 1990, there was extensive discussion about the demerits of this technique. Examples of bitumen coated earthen foundations exist in Chile (36), and the experiments with acrylic coatings were met with failure in Italy (37).

These failures led to the development of chemical treatment with chemicals which react with the various types of molecules in the earth in ways that consolidate them into stronger and more durable form. As defined by Dr. Neville Agnew,

> "Chemical preservation is the application of a substance, usually a polymer in solution or a monomer which converts in situ into a polymer, and confers its properties of durability, strength,(consolidation), weather resistance and so on." (38)

While there has been a variety of chemical treatments developed based on these principles, they can essentially be categorized according to their method of application and consequent results. The chemicals are applied by brushing or spraying. They penetrate into the structure gradually and react to bind and consolidate the soil molecules. They can also be applied by bulk infiltration, that is, by drilling holes into the earthen walls and pouring the liquid

Fig. IV.12. Spraying of chemical consolidants on adobe test walls, one of the methods of application.

chemicals inside with funnels. Bulk infiltration is also combined with surface application (39).

There are serious criticisms of this technique. The main criticism being that by chemical treatment the material earth is converted into a semi-artificial material, which does not have the natural properties of earth for which it is often advocated as a building material. The polymers or monomers so far being used for the consolidation of earth are synthetic. Thus the merit of earthen construction with the capacity of earth of being re-used may be affected. Buildings constructed with synthetic materials may also have serious detrimental effects on the future environment, specially in less developed countries where environmental controls and regulations are as yet inadequate.

Recycling is an extremely significant and important activity in a country like Bangladesh. For example, earthen products like bricks, tiles, pottery etc. are collected and crushed for other uses. Not much research has been conducted to assess the recycling potentials of chemically treated earthen products. Such assessment is important before chemical treatment of earthen products is considered for application. (40)

However, chemical treatment of historical structures is a separate issue from chemical treatment of new construction. While the debate whether to conserve historical structures or to bury them in the ground so that they may return to nature is a critical one (41), if we assume that conservation does have positive merits for society, then this technique offers unprecedented possibilities of retaining historically valuable structures of the past. In this case, a non-degradable quality is aspired for in order to prevent deterioration.

This technique has not yet been developed fully and applied on a large scale. The experiments of the Getty Institute for Conservation at The Fort Selden ruins in Las Cruces, New Mexico have not as yet yielded substantial results. The mechanical gadgets and high-tech mode of experimental research required to develop this technique is out of reach of a poor country like Bangladesh. The chemicals required are also not widely accessible. There can be no question that the application of chemical treatment for earthen structures is inappropriate for Bangladesh, especially at this stage when the technique is in its rudimentary stage of development.

The dilemma whether we should construct earthen buildings with synthetic properties is an important one. While the techniques of chemical treatment may have application in conservation projects it is important to decide upon the quality that we seek in our future environment. As in the case of the fired earth technique, the research in chemical treatment has to be conducted in developed countries. Hopefully future research in this area would lead to the development of organic based chemicals which would not alter the characteristics of the natural material earth, yet would be able to confer upon it properties of weather resistance and durability for a period of time to allow human habitation, and then allow it to decompose and gradually return to nature, to be used again and again in this way.

IV.4. STABILIZATION:

This is the most common and widespread innovative technique for the improvement of earthen construction. A definition of stabilization as provided by Soil Mechanics is,

> "Frequently the soils available for construction cannot meet the requirements, such as strength and incompressibility, imposed by their use in embankments or subgrades. The process of improving the soil so that it can meet the requirements is known as stabilization. In its broadest meaning, stabilization includes compaction, drainage, preconsolidation, and protection of the surface from erosion and moisture infiltration. However, the term stabilization is gradually being restricted to one aspect of soil improvement: the alteration of the soil material itself." (42)

This process of improving the soil consists of adding another material or a mixture of materials to the earth to be used for construction. Traditionally, materials such as straw, ash, salt, milk and even animal blood, among various other types of stabilizers have been used. There are local variations of these methods, and not much information is available about them. The most common practice is to add straw. In some places, such as in Iran (43), straw is added to a wet earth mixture, and allowed to rest for a while, sometimes as long as a week. The fermentation of straw releases organic juices which are supposed to behave as stabilizing binders. But as yet no extensive scientific research has been carried out which provide information on the effects of fermented straw as a soil stabilizer. Not to undermine the value of such regional practices, caution should be exerted, and if possible scientific verification should be attempted, before applying any such local practice. In any case, straw serves to increase the tensile strength and prevents cracking due to shrinkage of clayey soils. While this is an important additive to keep in mind, it does not belong to the category of stabilizers I will discuss, which alter the soil material in various ways.

Spence and Cook divide modern stabilizers into two main categories: binders and waterproofers (44). Binders are materials which bind the soil particles together by forming a network. They serve to increase the strength of the soil and in some cases also provide, to an extent, a water-repellent quality. Waterproofers are materials which are added primarily to provide a water-repellent quality to the soil. Portland cement and lime belong to the first category and bitumen (called asphalt in the U.S.A.) is the second. I will discuss these three stabilizers, their effects and potentials for applicability in Bangladesh.

IV.4.1. Cement:

The addition of cement to earth forms a cementitious product in reaction with water, which spreads out and fills in voids and porous spaces. This helps in binding the soil particles together and prevents the swelling and shrinkage which earth customarily undergoes in contact with water (45). This process does not make earth water-proof, but prevents it from decay from moisture and water.

It is pertinent to note that by cement I am referring to normal Portland cement, which is the most common type available in Bangladesh. There is a variety of different cements, each with their specific properties. For the lack of sufficient experimental data regarding soil stabilization with different types of cement, I will restrict this discussion to soil stabilization with normal Portland cement.

Soil stabilization with cement works well with sandy soils, as the particles are large enough for binding. But in the case of clayey soils, clay also reacts in the soil in a similar way as cement by forming a binding matrix. The clay particles are too small and therefore large amounts of cement are required for effective stabilization of clayey soils. As mentioned before, the soil of humid flood plains like Bangladesh contain a high amount of clay. Hence, stabilization with cement is not a suitable technique as it will increase costs considerably. The aim of this study is to search for cost effective ways of building for the poor context of rural Bangladesh, and in this regard cement fails to fulfill the criteria. As yet Bangladesh does not produce cement and all the supply of cement in the country is imported, which makes cement an extremely expensive commodity and in most rural areas a scarce one.

The other problem with cement is that it sets very quickly. This is useful only in the case of producing stabilized soil-cement blocks, but in the case of other forms of earth construction, such as wattle and daub, it may prove to be a disadvantage. The preceding discussion pertaining to pressed earth blocks deemed them unsuitable for the context of Bangladesh. But in the case of the choice of sun-dried bricks, the possible use of cement as a stabilizer may be considered, if the benefits outweigh the high costs. This may be a very hard decision, and in all probability will be too expensive for most of the rural inhabitants of Bangladesh.

Though the high cost of cement prevents its widespread application, theoretically it has the potential for application as a stabilizer in the northern areas of Bangladesh. This is the same area which has a tradition of earthen buildings built in the layering technique. The soil

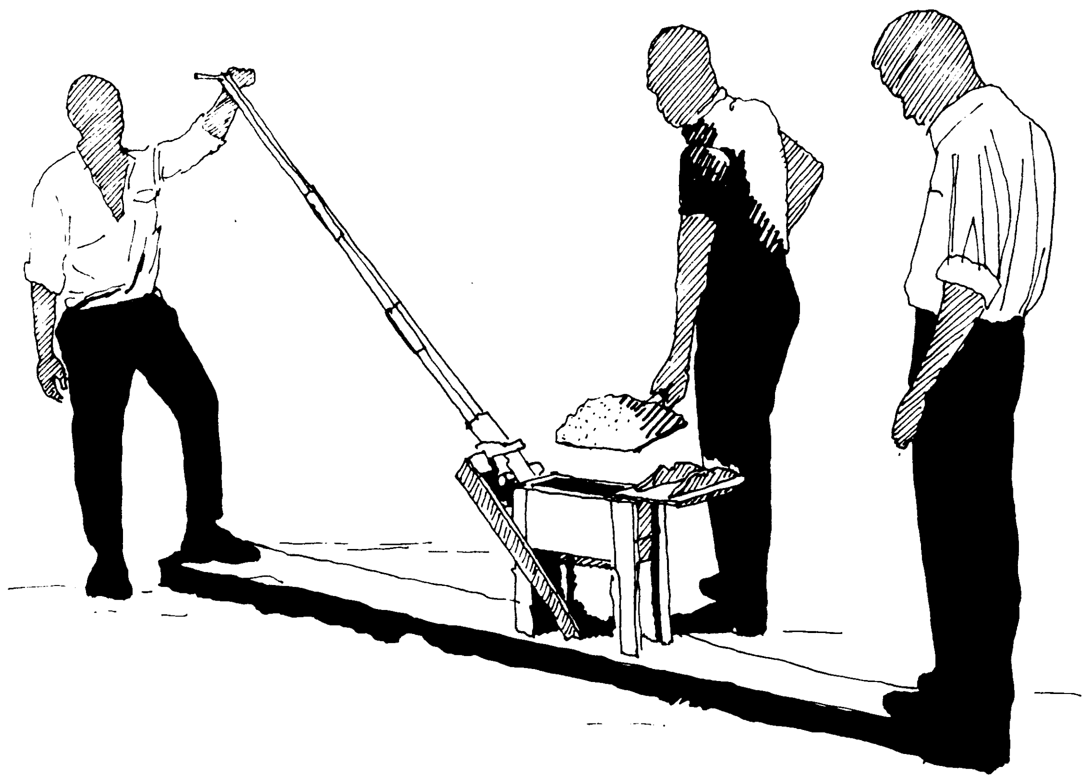


Fig. IV.13. Molding cement-stabilized earth blocks with the CINVA-Ram.

in this area is not very clayey, as it is not exactly a flood plain and is relatively dry. Small amounts of cement can be used for stabilization, but it will not be possible to use the stabilized soil for the layering technique. The use of cement stabilized sun-dried bricks may find some application there.

IV.4.2. Bitumen:

As mentioned earlier, bitumen is water-repellent and stabilization with bitumen reduces the swelling and shrinking effects of earth in contact with water. Bitumen is dissolved in some solvent, such as kerosene under high temperature conditions, and mixed with soil. As the mixture dries, the solvent evaporates, leaving a coating of bitumen around the soil particles, which serves to mitigate moisture attack (46).

Bitumen works best on soils which are "low clay/high sand" (47) for making compacted blocks. This is because it can form coatings around the large grains. But again, this is not the type of earth available widely in the flood plains of Bangladesh. On the other hand, bitumen works also well in sun-dried bricks made out of "high clay/low sand" (48) earth, and have been widely used in many South American countries. But this necessitates the use of a higher amount of bitumen which results in reduced dry compressive strength

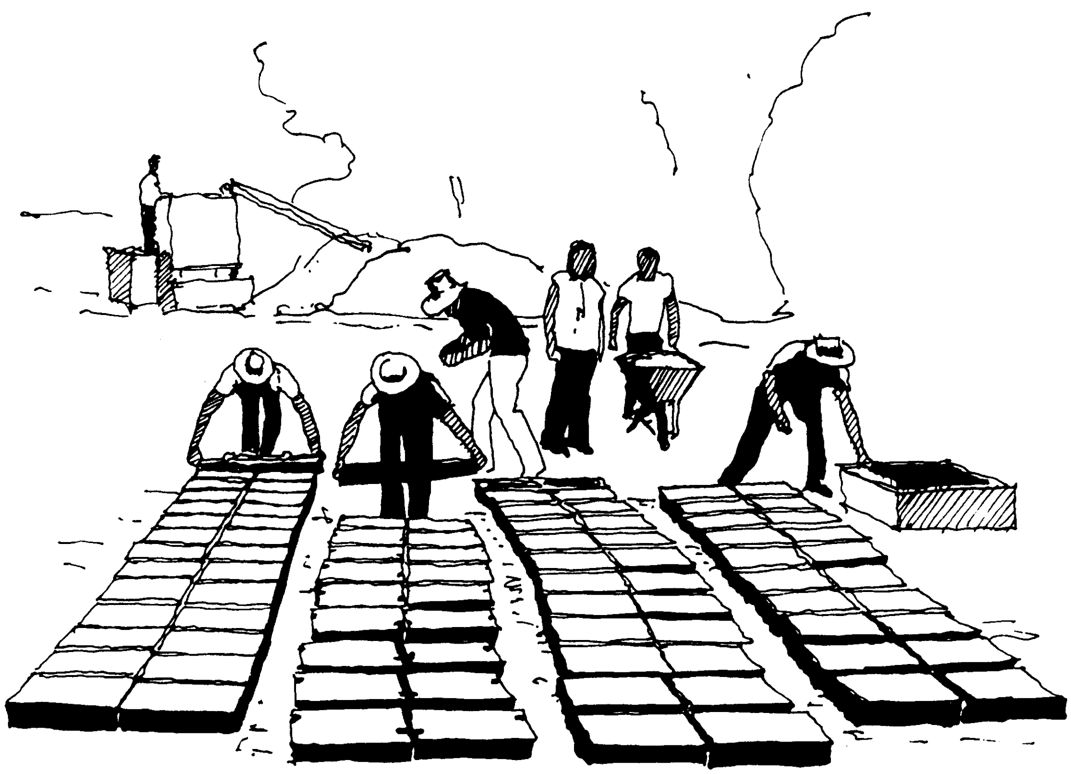


Figure 3.19 Adobe block manufacture in Peru

Fig. IV.14. Bitumen stabilized adobe block production in Peru, South America.

and higher costs (49). As mentioned before, keeping costs down is an important criteria, and the decision to use bitumen as a stabilizer for sun-dried bricks has to be evaluated in terms of the real gains, if any.

The use of bitumen as a building material is not very widespread in Bangladesh. Conventional water-proofing on flat roof surfaces is done by lime terracing, and this practice has been carried on even on concrete roofs in modern buildings. Bitumen is used in damp-proof courses for brick foundations in modern buildings to prevent rise of subsoil water into the walls. It is also widely used for street surfaces. It is available to an extent and it may be possible for rural builders to obtain limited access to it. But it is certainly not a material which is cheap and widely available. Its introduction for stabilizing sun-dried bricks may fulfill the need to develop a viable earthen construction technique, but it also necessitates the introduction of the application of new product and distribution system.

Sun-dried bricks stabilized with bitumen have the potential for limited application in rural Bangladesh. As mentioned before, sun-dried may be used in the interior institutional buildings, without stabilization and stabilized bricks can be used on the exterior surface exposed to the elements. Institutional buildings are often funded by external sources, sometimes by the government, and such funding can be tapped as a resource to improve local building traditions. The application of new technology in public buildings is a way to introduce new product lines to other private and domestic building types (50), and this notion may serve well for developing a suitable innovative earth architecture in rural Bangladesh.

IV.4.3. Lime:

Unlike Portland cement, lime works best as a stabilizer for soils with a high clay content. Lime by itself cannot form a cementitious product, but it reacts with certain minerals in the clay to form a cementitious, insoluble gel (51). For the clayey earth of the flood plains of Bangladesh, lime is certainly an effective stabilizer. The effect of lime for stabilizing earth works in two main ways,

> "(1) by reducing the soil´s expansive qualities and (2) by forming a moisture barrier which prevents water from reaching the expansive soil." (52)

These are the ideal qualities sought for in a stabilizer. However, it takes a long time for these effects to take place, and in some cases may take as long as six months for the soil to consolidate fully. The addition of certain materials, most commonly burnt clay powder reduces the time for setting of lime stabilized soil and produces a much stronger crystalline bond for the soil molecules. This powder, known as "surkhi" in the Indian sub-continent, is available widely as it is used for lime terracing of flat roofs. It is collected from broken pottery, bricks and other waste from ceramic products. It is produced on quite a large scale by crushing those products and is a source of employment for many people. The reaction of lime with "surkhi" is known as a pozzolanic reaction, it is an ancient technique, and is capable of producing extremely durable and weather resistant products.

The other advantage of stabilizing with lime-pozzolanic stabilizers is that it does not set as fast as Portland cement and hence is easily workable for different forms of earth construction, such as wattle and daub, and layering, among many others. When lime is mixed with earth it has a distinct setting effect and therefore can be worked with in rainy weather, which is a practical consideration in the case of Bangladesh, where rain is frequent and often building construction has to be carried out in spite of rainy weather.

Lime is a widely available product, and prepared both in hydrated and slaked form (53) in Bangladesh and is utilized as a building material for various purposes, among them lime terracing, lime plastering and whitewashing being the most common. Lime is usually obtained there from shells or by leaching sand and in some areas from limestone quarries. In any case, it is a cheap and commonly available

Fig. IV.15. "Surkhi" production from broken bricks ib Bangladesh. Utilization of scarce resources and labor intensive production.

material and can be utilized for stabilizing earth, the other cheap and easily available material.

IV.5. SUMMARY:

Various innovative techniques have been developed with the intention of retarding the decay of earthen structures. These can be categorized into four main techniques - compaction, firing, chemical treatment and stabilization. Compaction is capable of producing two main products - rammed earth structures and earth blocks. There are two types of earthen blocks, one is the CINVA-Ram compacted blocks and the other is uncompacted sun-dried bricks. Firing is the method by which a completed earthen structure is fired from within to confer properties of durability to it. The Getty Institute has developed chemical treatment methods for conserving deteriorating earthen structures and also for application in new construction. Stabilizers are substances which are added to earth to increase its durability. The most important types are cement, bitumen and lime.

There are serious disadvantages with all these methods when assessed with regard to potential for applicability in Bangladesh. In particular, some of the techniques would be prohibitively expensive in a popular context. Yet some do have the potential for relative economy in that context, among them chiefly sun-dried bricks and stabilization with lime seem best suited for further development, with the intention of their eventual widespread application.

------------------------- NOTES ----------------------------

1. Nader Khalili, Ceramic Houses (Harper and Row, San Francisco, 1986), p.25. Translated from a Persian poem.

2. See R.J.S. Spence and D.J. Cook, Building Materials in Developing Countries (John Wiley & Sons Ltd., New York, 1983), p.46-47.

3. For descriptions of rammed earth construction in the southwestern U.S. see Magnus Berglund, Stone, Log and Earth Houses, (The Tauton Press, Inc., Watertown, Connecticut, 1986), pp.95-147. Also see David Easton, The Rammed Earth Experience (Blue Mountain Press, Wilseyville, Calif., 1981). Easton is notable for his innovative formwork for rammed earth construction.

4. Rammed earth construction methods in Morocco have been documented extensively. For example see, Jean-Louis Bourgeois, Carolee Pelos and Basil Davidson, Spectacular Vernacular (Aperture Foundation, Inc., New York, 1989), p.58. Also, Jean-Louis Michon, "Mud Castles (Kasbas) of south Morocco - will they survive?", Getty Institute for Conservation, Proceedings of the 6th International Conference on the Conservation of Earthen Architecture (Adobe 90 Preprints) (Las Cruces, New Mexico: n.p., 1990), pp.99-104.

5. Anthony D. King, The Bungalow (Routledge and Kegan Paul, Boston, Mass., 1984), p.20.

6. O.H. Koenigsberger, T.G. Ingersoll, Alan Mayhew, S.V. Szokolay, Manual of tropical housing and building (Longman Inc., New York, 1973), p.218.

7. John Norton, Building with earth (Intermediate Technology Publications, Rugby, U.K., 1986), p.38.

8. Lloyd Kahn (ed.), Shelter (Shelter Publications, Inc., Bolinas, Calif., 1973), p.68.

9. Ibid.

10. Spence and Cook, p.308.

11. M.P. Chrisholm, "Bangladesh Rural Housing Vol.I" (Bachelor of Architecture thesis, University of Newcastle upon Tyne, England, 1979), p.68.

12. This is quite a common practice, as evidenced by various books on earth construction in the southwestern U.S. For example, see John F. O´Connor, The Adobe Book (Ancient City Press, Santa Fe, New Mexico, 1973), p.50, where he describes the technique of plastering earthen walls covered with fine-screen wire mesh.

13. See Maria Elena Molina, "Prevencion sismica en las construcciones de adobe, en la ciudad de Guatemala despues de los terremotos de 1917-1918" (in Spanish), Adobe 90 Preprints, pp.331-335. Here she has described how the plaster on the earthen walls with wire base failed during mild earthquake tremors.

14. John F. O´Connor, p.50.

15. James W. Garrison, "The evolution of adobe construction systems in the southwest (USA) and related conservation issues", Adobe 90 Preprints, p.55.

16. See Nazimuddin Ahmed, Discover the monuments of Bangladesh (University Press Limited, Dhaka, Bangladesh, 1984).

17. King, quoting from the Imperial Dictionary, p.37.

18. See L.J. Goodman, et. al., Low-cost housing technology (Pergamon Press Ltd., New York, 1979), p.209.

19. Berglund, p.103.

20. Ibid., pp.103-105.

21. George B. Sowers and George F. Sowers, Introductory soil mechanics and foundations (The Macmillan Company, New York, 1970), pp.45-48.

22. See Nader Khalili, Racing Alone (Harper and Row, New York, 1983), where he describes his discovery and early experimental construction of the firing technique. Also see Ceramic Houses, where he has provided construction methods and details for firing earthen buildings.

23. For more descriptions of Ray Meeker´s work in India, see Ray Meeker, Elements 4 (April 1989): 3, 9.

24. Khalili, Ceramic Houses, p.26.

25. Ray Meeker´s pottery and firing operation is supplemented by a small scale timber production, which presents a renewable source of energy.

26. See Spence and Cook, pp.308-309.

27. See U.S. Department of Housing and Urban Development, Agency for International Development, Ian Donald Terner and John F.C. Turner, Industrialized housing, pp.IV-5 -IV-11.

28. For details of burner, see Khalili, Ceramic Houses, p.159-162.

29. Khalili, Racing Alone, p.vii.

30. Ibid., pp.14-17. Here Khalili describes his discovery of the firing technique inspired by old brick-firing kilns in Iran. The kilns are as large as a small room, and this was the source of the idea that such kilns can be used as dwellings, after firing earthen products inside them.

31. Daniel Rhodes, Clay and glazes for the potter (Chilton Company, Radnor, Penn., 1957). pp.234,238.

32. Ibid., p.57.

33. Ibid.

34. See Khalili, "Designing Lunar Habitations," Mimar 32 (June 1989): 25. For a detail description of the dome in New Cuyama, see Patrik Schumann, "´Sunrise Dome´ Fired in California," Elements 4 (April 1989): 1, 7-8.

35. Adobe 90 Preprints, pp.243-260.

36. Ibid., see Edwin Binda Compton, "Arquitectura vernacular del valle central de Chile" (in Spanish), pp.8-13. Also see, Garrison p.54, where he describes the practice of capping earthen foundations with bitumen.

37. ICCROM (International Centre for the Study of the Preservation and Restoration of Cultural Property) has done some work in this regard.

38. Adobe 90 Preprints, p.244.

39. Ibid., pp.245-246.

40. An insight into bio-degradation and waste recycling has been provided by William L. Rathje, "Once and Future Landfills", National Geographic, May 1991, pp.116-117.

41. See Alois Reigl, "The Modern Cult of Monuments: Its Character and Its Origin", Oppositions 25 (Fall 1982): 31-34. Regarding the cult of "age-value", he has written, "Every artifact is thereby perceived as a natural entity whose development should not be disturbed, but should be allowed to live itself out with no more interference than necessary to prevent its premature demise." (p.32). Also, "The cult of age-value, then, stands in ultimate opposition to the preservation of monuments." (ibid.)

42. Sowers and Sowers, pp.233-234.

43. See Khalili, Ceramic houses, p.132. Also see Gus W. Van Beek, "Arches and Vaults in the Ancient Near East," Scientific American, July 1987, p.96.

44. Spence and Cook, pp.46-47.

45. Ibid., pp.49-53.

46. John Norton, p.56.

47. Ibid.

48. Spence and Cook, p.55.

49. Ibid.

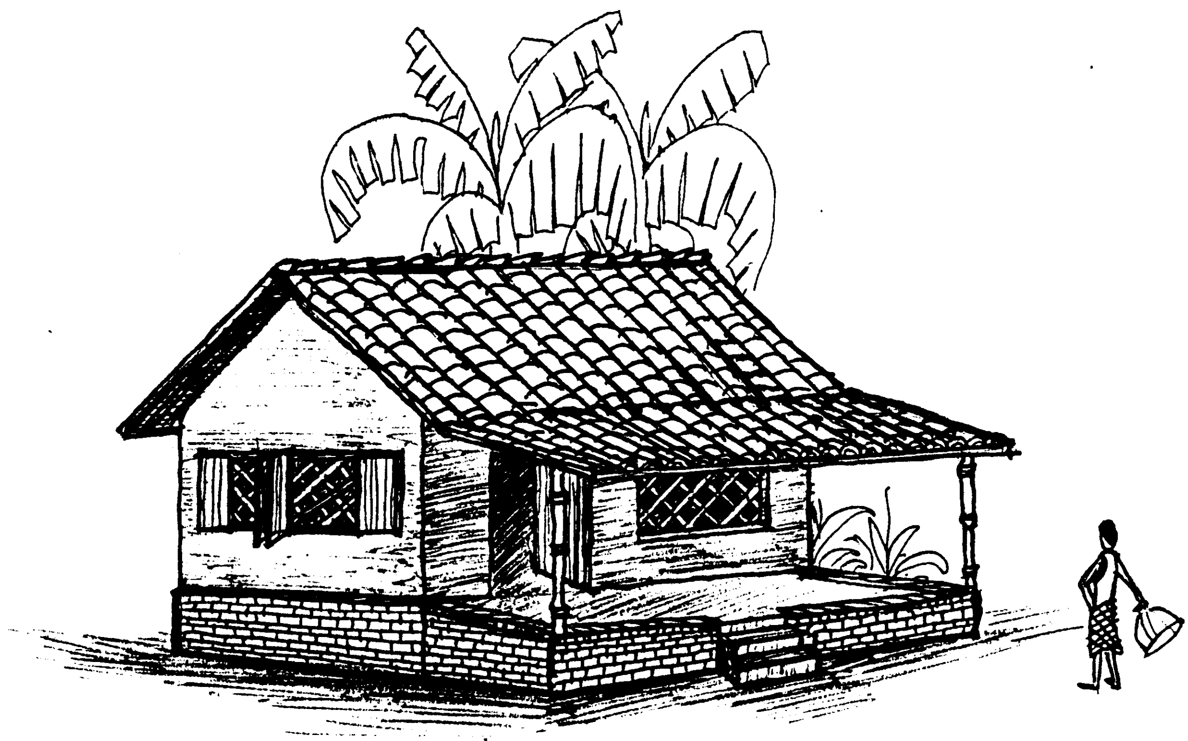
50. See Chapter II notes, note 12.

51. Spence and Cook, p.57.

52. Don A. Watson, Construction materials and processes (McGraw-Hill, Inc., New York, 1978), op. cit., p.30.

53. For information about lime and its properties see, Caleb Hornbostel, Construction Materials (John Wiley & Sons, New York, pub. date unknown), pp.411-412.

CHAPTER V



"Resigning himself, Saddhu ate the meal which was not even enough for one person, then lay down on his tattered mattress in the dark hut. He could see fragments of the sky between the cracks in the thatched roof, through which some sleepless stars seemed to be gazing at him with a melancholy look. The sky reminded him of a sari he had promised Hamida, sparkling with stars and silky. How he longed to see Hamida dressed like an angel. Suddenly, his gaze shifted downwards where rats raced along the mud walls of the hut. Saddhu turned over on his left side and tried to sleep." (1)

CHAPTER V. IMPROVEMENT, APPROPRIATENESS AND APPLICATION

V.1. MOVEMENTS TOWARD CHANGE:

There have been essentially two different developments at different times in the utilization of techniques for improving the architecture of less developed countries. The first one is the notion of "Tropical Architecture", and the subsequent development stemmed from the "Appropriate Technology" movement. These vary substantially in essence and ideology. Yet both these developments stem from the basic premise that traditional architecture in the so called "Third World" (2) requires improvement, or in any case modification, in order to render it capable of adapting to situations demanding change. These two developments are not mutually exclusive, rather they represent progression on the same continuum or time-scale. The following discussion attempts to critically evaluate and analyze these two developments in utilizing techniques of improving local architectures.

V.1.1. "Tropical Architecture":

The colonization of countries in the tropics in Asia and Africa was characterized by the subsequent arrival of colonial officials in those countries. Those officials were accustomed to the colder temperate climate of Europe, and the arrival into climates of considerable difference naturally caused discomfort, and the need arose to change or develop an architecture suitable for habitation by Europeans.

T. Roger Smith was among the first to deliver a paper to the Royal Institute of British Architects in 1868, which marked the beginning of "tropical architecture" (3) as a topic of study. His experience was mainly of India, and of the control of climate through building form for the comfortable habitation of Europeans. It must be stressed here that Smith´s tropical architecture was primarily concerned with climate and not very much with other issues.

King has described the evolution of the architecture based on the principles of "tropical architecture" in India as "an appropriation of culture" (4). Much of the form of the British colonial "bungalow" was derived from local forms, materials, labor and techniques. In spite of this, King´s notions about this kind of architecture being associated with colonial tyranny, it was extremely responsive to the climate and local environmental conditions, which is something he has overlooked. The forms were rooted in local traditions,and were largely built using local labor and materials, and consequently, to a large extent, were reflections of the past, and hence the phenomenon may be termed as acculturation, and not a process

Fig. V.1. A British colonial building in Bengal, 1914. A case of acculturation.

of appropriation. Here I am referring to the bungalows and other buildings which were derived from local practices, not the European classical models which were also used in India.

In the mid-twentieth century, the formation of the Architectural Association's Tropical School under the direction of Otto Koenigsberger stemmed from the need for provision of colonial buildings to be built in the tropics. The major part of the architectural education in that school was devoted to climatic studies and the domination of climate through architecture. However, at that time the notion of building climatically suitable buildings for Europeans in tropical regions was broadened to include also architecture for the natives, often in the form of workers' housing (5).

This notion of architecture for the less developed countries was continued till the 1960s, until it came to be influenced by the humanistic ideals of the Appropriate Technology movement. The two were very closely related.

V.1.2. Appropriate Technology:

The newly evolved concepts of architecture based on the Appropriate Technology movement were being taught at the Architectural Association school in the early 1960s. The group called the "Development Workshop" grew out of that (6). If there was a founder of "Appropriate architecture",

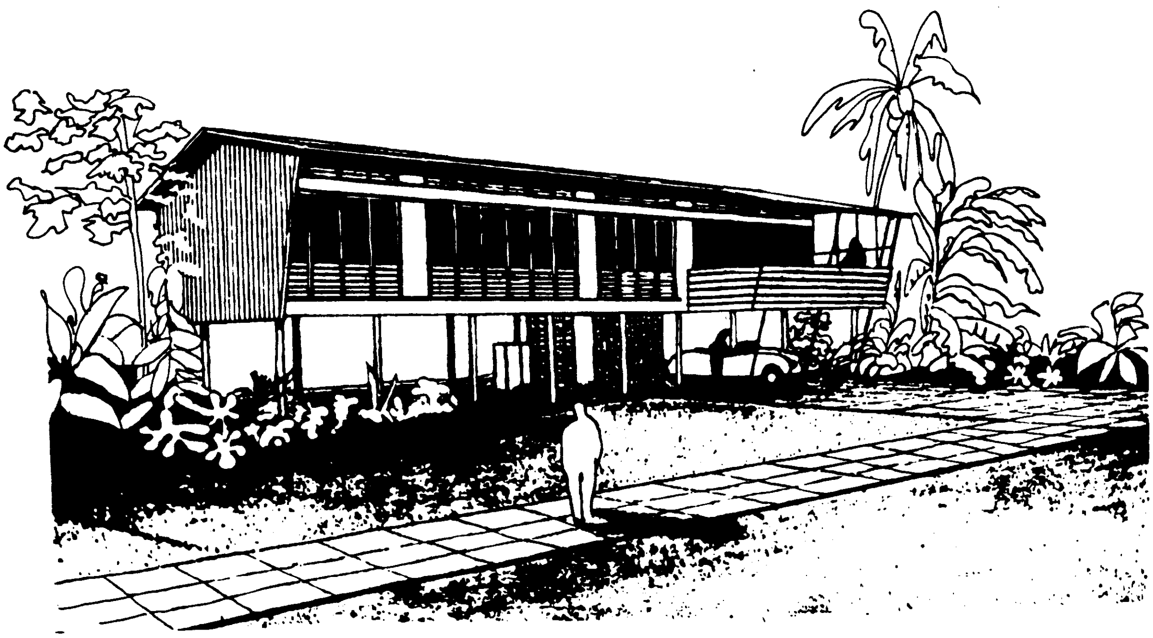


Fig. V.2. Employee housing in Australia, 1933.

it was Hassan Fathy, though somewhat unintentionally. His book "Architecture for the Poor" (7) was first published in the 1950s. His writings and work in Egypt represented the earliest attempts to develop the architecture there based on indigenous practices.

An important influence on the Appropriate Technology movement was F. Schumacher, who with his book "Small is Beautiful" (8) brought attention to the problems of industrialized countries and the absence of those problems in less industrialized countries. The basic idea was to allow the less developed countries to develop in a different way so that they do not follow the development pattern of the industrialized countries.

In architecture this notion was supported in different ways by prominent writers of that period - Bernard Rudofsky, John Turner, Charles Abrams - to name a few. The name of Paul Oliver is important in this regard for his extensive writings on indigenous architecture around the world, and who was a moving spirit at the AA school. It was felt at that time that there was a serious need to seek new directions for an appropriate architecture for the less developed countries. It was believed that this architecture was to be rooted in indigenous practices, yet should be able to perform according to the needs of the contemporary period. The development of this new architecture was to be coupled with the education of "Third World" professionals, who until now have been educated according to the dictum of the profession as it existed in the industrialized countries. Unlike the earlier concepts of "tropical architecture", this architecture was to be for the natives of the less developed countries, not only for European expatriates. It is important to note that most of Koenigsberger´s students were from abroad, and mainly from less developed countries.

Addressing this change, Ronald Lewcock, who was a professor at the AA school, had written,

> "Third World studies have become more than mere climatic studies. To the old ´architectural design in the tropics´ have been added the many aspects of the upgrading of local technical resource and a whole spectrum of studies in inherited patterns and meaning in society." (9)

As with the concept of appropriate technology, this notion of architecture can take two forms - evolutionary and revolutionary. The concept of "intermediate technology" as proposed by Turner (10), is an evolutionary one, where the intermediate solution is seen as a step to achieve development, or evolve, in the role-model of the industrialized countries. Whereas the revolutionary concept implies that the development in the industrialized countries is inherently wrong, and an alternative to that role-model should be formulated, leading to the concept of "alternative technology". Witold Rybczynski has described the Appropriate Technology movement as being conceptualized by its proponents in either one of these forms (11).

In my opinion, the distinction between these two forms is not such a clear one. Some aspects of the new architecture for the less developed countries may be revolutionary, whereas some aspects are to be evolutionary. A balance between these two, that is between innovation and tradition, has to be achieved in order to create suitable architecture for the context which it is for. This balance is certainly not a universal solution, it varies according to the context. Therefore, the training of professionals in "Third World" architecture should attempt to instill a sense of judgement in the minds of the professionals so that they can achieve the suitable balance between tradition and change according to the context.

The work of the Development Workshop should be mentioned in this regard. This group worked for three years with Hassan Fathy at the beginning, the last year advising the government of Oman on what should be done about architecture there. The following description by them of their work, provides a key to understanding the relation between the apparently unrelated concepts of evolution and revolution:

> "Firstly, designing the intervention on a thorough understanding of the indigenous resources - human and natural, value systems, materials and technologies - prevalent in the community is important." (12)

This is the revolutionary aspect of the work. At a time when the less developed countries are ignoring their own traditions and attempting to copy the architecture of the industrialized countries, the reference to indigenous resources suggests an alternative to the architecture based on exogenous resources which is rapidly replacing indigenous architecture. It is revolutionary in the sense that it is opposed to the popular, and also bureaucratic notions of architecture, in the less developed countries which is bent upon imitating a foreign architecture.

> "Secondly, the aim of the intervention has to complement the strengths of the indigenous resources to overcome the identified shortcomings within them." (13)

This represents the evolutionary aspect of the work. The standards of health, sanitation, education and permanency in architecture has evolved in the "Western" countries. It is with these higher standards that the existing indigenous architecture is being judged. The appropriateness of applying these standards can be debated, but in general it may be claimed that such standards are adopted to reduce human misery and improve the living conditions of people in the less developed countries.

Some perceive the revolutionary aspect of this new approach to architecture as a counter-modernizing movement and a revival of vernacular architecture out of a nostalgia for the past. This is not really the case here; rather it is a judicious appreciation of the qualities of indigenous architecture, which is lacking in the architecture of the industrialized countries.

Witold Rybczynski has reflected on his experiences in development work in the less developed countries, and in 1980 has commented,

> "For almost all of the less developed countries, a reversion to a traditional society is an impossibility; they have passed the point of no return." (14)

Increased population, and hence increased need and also resource-depleted environments are some of the influencing factors that require new responses of architecture, involving new building programs and entirely new types of solutions; such demands did not exist in the past, therefore there was no necessity for change. In addition, polarization of wealth and corruption introduce new factors which affect the building industry. These changes make it impossible to return to the past state of harmony and therefore new ways to build must be considered. If at all traditional societies are to retain the essence of their culture and yet perform adequately to the demands of the present age and progress towards the future, such new notions have to be considered.

V.2. EARTH AS A BUILDING MATERIAL:

I have chosen to deal with this topic here, because as a consequence of my concept of a suitable architecture for less developed countries, the following inquiry is inevitable: If there is a need for a suitable architecture for rural areas in Bangladesh, what role does the traditional material earth play in construction?

As mentioned earlier in Chapter I, this thesis is essentially a study of indigenous materials and building practices in Bangladesh, with the intent of suggesting potential improvements. In this regard, earth is one of the materials used predominantly and extensively in the rural architecture of Bangladesh, but of course is not the only indigenous building material. One of the characteristics of Bangladeshi architecture, in most rural areas, is the diversity of building techniques. A variety of building materials are used in different ways, which creates complexity in the built environment. A survey of a village by the Bangladesh Centre for Urban Studies revealed this diverse character (15). Therefore, any attempt to modify rural architecture in Bangladesh should recognize this diversity and allow for its manifestation.

In this thesis I have chosen to deal with one major building material in Bangladesh - earth. Though I have and will deal mainly with this material it does not mean that I am excluding the possibility of the use of other indigenous materials - wherever possible they are dealt with in combination with earth -the reason for the term "earth-derivative architecture". This also includes the possibility of the other materials being used exclusively without earth being one of the ingredients, but this thesis is not the place for the elaborate discussion of this

Fig. V.3. The rural environment in Bangladesh consists of a diversity of building materials and their combination.

possibility.

As in chapter IV, where I have assessed the applicability of various innovative techniques, I will propose applications of earthen construction in the light of overall benefits and costs. The context and conditions of the applications have been delineated earlier, and thus the application possibilities should be viewed according to the context in a broad sense of the overall costs and benefits. This approach has not always been followed and greater importance has been placed either on cost or benefit, consequently resulting in inappropriate architecture (16).

In the following sections, I will discuss the potential for the use of earth by considering the major parts of the building separately. The emphasis will be mainly on wall construction techniques, as these are the areas in which earth has maximum applicability. However, the other parts of the building will be considered in order to strive for a degree of harmony in the overall architecture. Wherever necessary, I will refer to the various physiographic areas of Bangladesh, to relate to existing building forms which have evolved according to the environmental conditions.

V.2.1. Foundations:

Foundations constitute a special problem in buildings in the wet climate of Bangladesh. Following earlier analyses (chapter II), within each region, there are three main approaches to the construction of foundations:

a. Earthen buildings built by the layering technique in the Pleistocene region often do not have foundations; instead a mound of rammed earth or a raised plinth is built, upon which the walls are built directly. The plinth often absorbs the direct capillary action of dampness rising from the ground into the walls. Also, the floor often admits rising moisture from the ground and can become quite wet. In the houses of the more affluent, a raised plinth of fired brick is constructed using a concrete slab and stepped fired-brick foundation, upon which the earthen walls are built. This is certainly a practical technique, and whenever possible such a practice should be encouraged. Instead of Portland cement to cast the concrete slab foundation, the possibility of using lime-based pozzolanic cement should be explored. Such a cement would reduce costs and utilize locally available materials as well. Well fired bricks do not need to be plastered as they are resistant to deterioration by exposure to water. It is a question of human choice to plaster them, and education and technical advice may help to influence decisions regarding the necessity of plastering.

The problem of avoiding a moist floor in the raised earthen plinth is a serious one in some areas. Instead of having a cement floor, the alternative would be to cover the

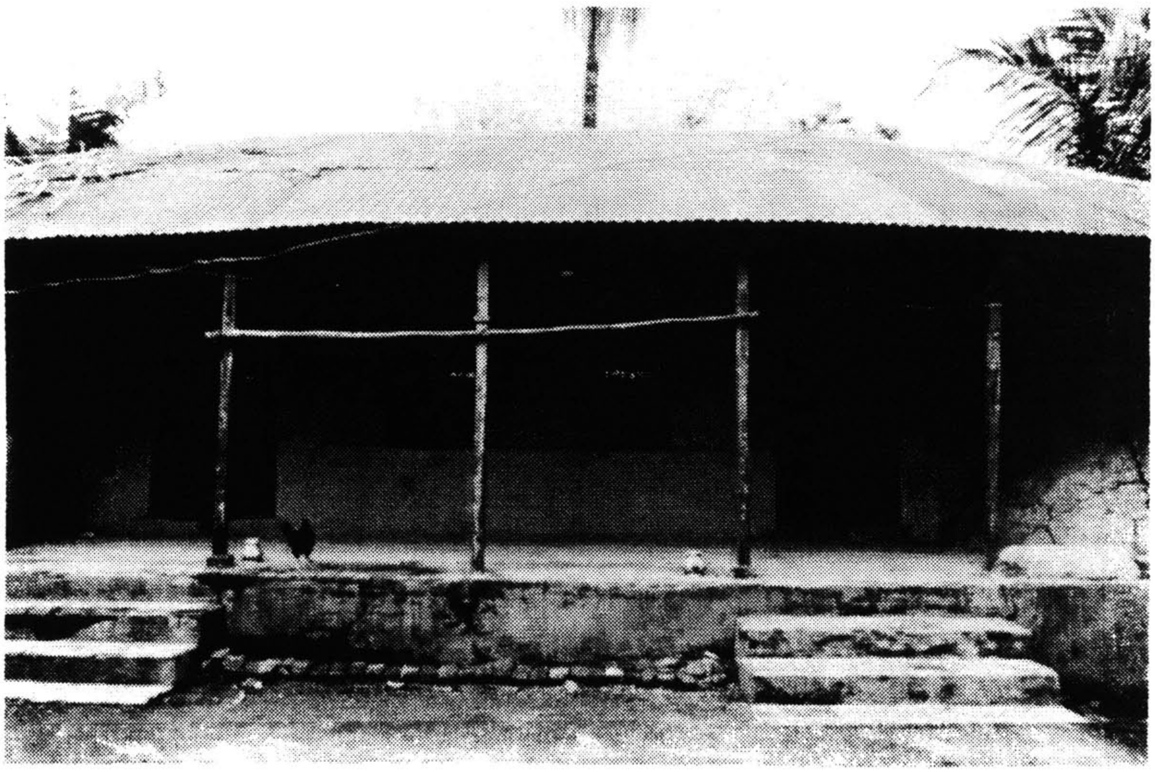


Fig. V.4. Raised plinth of brick and concrete upon which the earthen walls are built.

floor on the raised plinth with fired bricks without any mortar. A layer of lime-pozzolanic cement below the bricks would protect the floor from rising dampness. Fired bricks are available and produced in Bangladesh, but in general they are too expensive for the poor. Such a solution can be implemented slowly in increments, upon consideration of the overall costs and benefits. Even in cases where the fired bricks are unaffordable, the lime-pozzolanic cement layer would mitigate the capillary action to a large extent.

The exterior surface of the earthen plinth can also be clad with fired bricks, to protect it from water. But it is an important fact that in the absence of brick the maintenance of the earthen plinth is carried out seasonally by the owners of the house. A layer of mud slurry mixed with cow dung is used for plastering the exterior surface of the plinth in the short dry period following each monsoon season. Note that the introduction of a new system of maintenance may disrupt established cultural practices and may have serious consequences.

b. In some cases a foundation trench is dug and the earthen walls are built upwards in layers from within these trenches. In order to prevent the capillary rise of sub-soil water, the earth within these trenches is thoroughly compacted before the walls are built. This is an efficient technique and I see no reason why it should not be

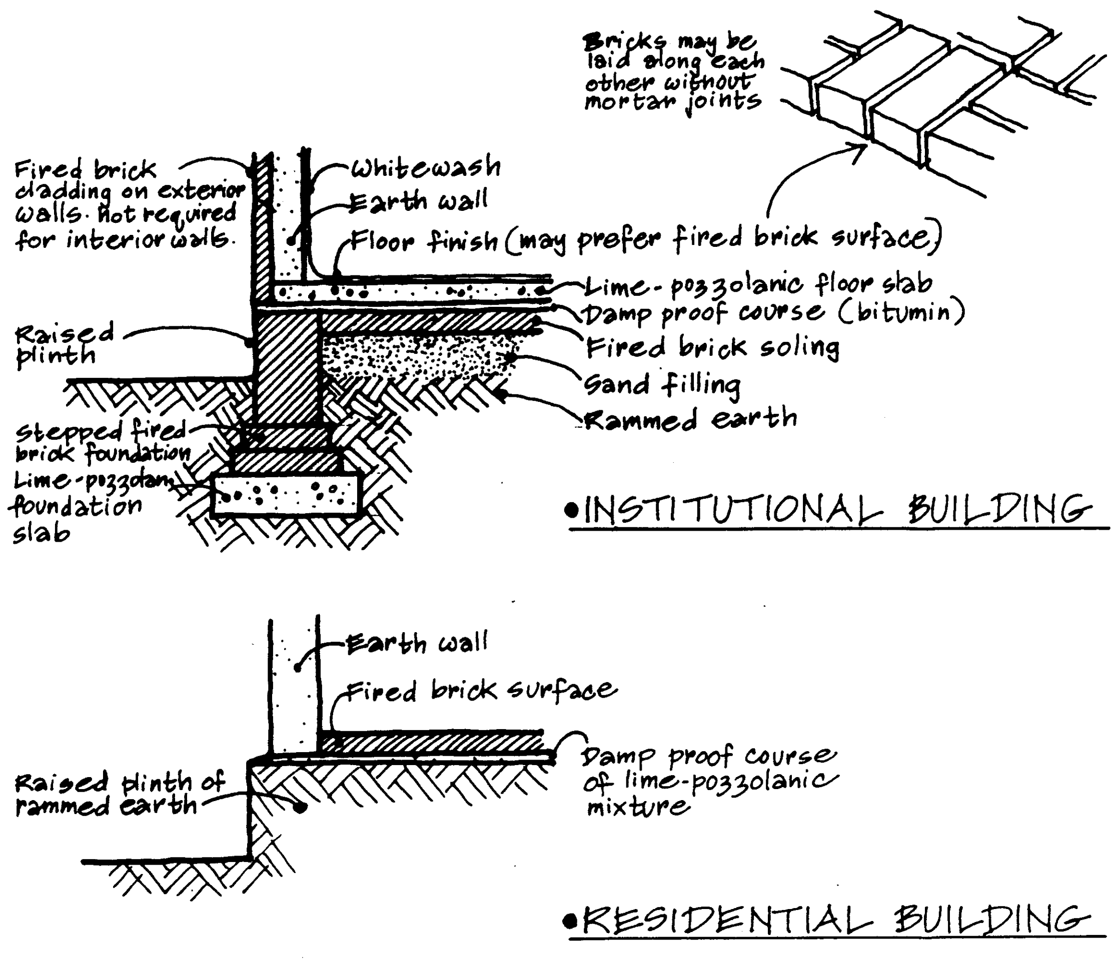


Fig. V.5. Some methods for damp-proofing floors of earthen buildings.

continued. It is evident that this practice is prevalent in drier areas where the sub-soil water table is low. Such a technique cannot be utilized in the really wet areas.

c. In the areas where there is a higher prevalence of bamboo buildings, the roof structure is supported by bamboo poles and the bamboo mat walls are free-standing, and rest upon the raised earthen plinth. It is an important fact that in marshy parts of the delta region, the earthen plinth is not built, rather the building is raised on bamboo stilts, and sometimes on timber stilts. It is interesting that the same construction technique is employed in hilly areas, not for flood-protection but to site the building on uneven terrain. The floor in such stilted buildings is also built of bamboo, or in some cases with rough wooden planks.

Constructing buildings on stilts is certainly a practical method of flood protection. However, the problem in this case is that after prolonged contact with water or moist soil, the timber or bamboo posts are subject to decay, therefore these buildings cannot last long. Even in the case of bamboo buildings which are not stilted, the bamboo posts supporting the roof are embedded into holes dug into the ground. This way the poles are vulnerable to termite attack, as well as damage due to rotting in the moist soil.

For this reason, it has been a recent practice in some areas, for the part of the bamboo pole which is to be

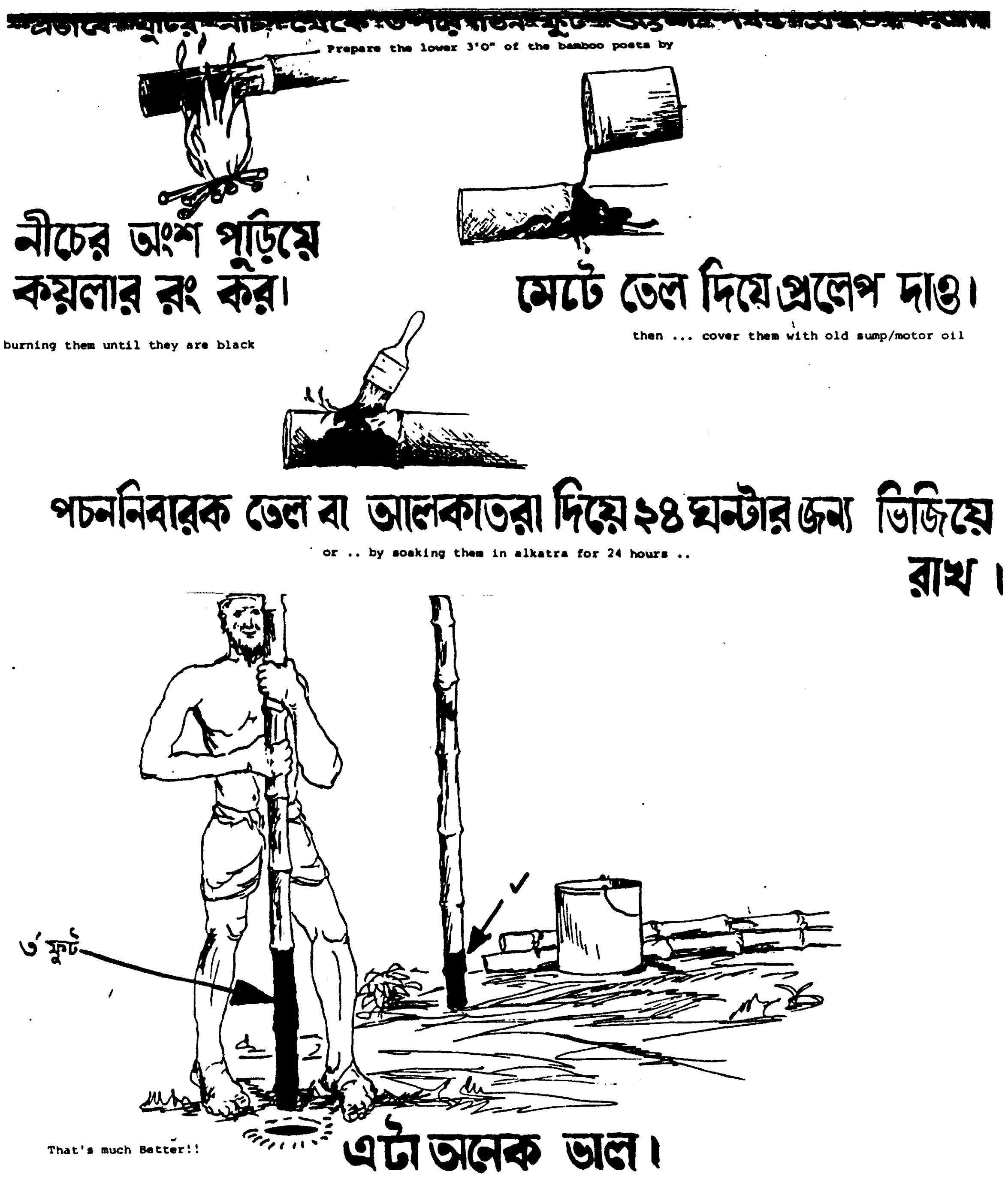


Fig. V.6. Treatment of part of bamboo post to be embedded into the ground.

embedded into the ground to be treated against damp penetration. The lower part of the bamboo post is first burnt until it is black. Then it is covered with a coating of old sump/motor oil. Where it is available, bitumen is used instead of motor oil to provide the waterproofing coat. This kind of treatment also reduces termite attack. Such a practice is slowly becoming popular, and as the amount of bitumen or motor oil needed is rather low for the posts of residential buildings, it is in most cases affordable. The use of sump/motor oil is cheaper than bitumen as it is generally an industrial waste product.

The functional characteristics of such a method of treatment can be described as follows: the decay of timber by micro-organisms and insects occurs in the moist areas of the timber, which contain cellulose, or that develop fungi, from both of which the insects derive nourishment. As has been observed by many restorers, the dry areas of timber in old buildings are relatively unaffected by insect action, as compared to moist areas. By scorching the bamboo post, it is dried out completely, thereby retarding insect attack. After scorching the post, coating it with a layer of bitumen or sump oil further prevents the access of insects to the bamboo material. This coating has the additional benefit of protecting the bamboo post from attack by ground water.

The Bangladesh Institute of Engineers has proposed stilted construction using concrete columns for use in the coastal areas (17). Regarding the high cost of such construction M.P. Chrisholm, has written,

> "This cost is beyond 98% of the occupants of the coastal areas, and represents the equivalent of 30 bamboo/thatch houses, or 25 years wages!" (18)

I will not discuss this further as it is evident how unsuitable such a form of construction is for a poor country like Bangladesh. Solving a problem with high technological solutions is not the mode of improvement this thesis seeks to address. My essential purpose is to explore methods of improvement which will be affordable, accessible and easy to apply in the context of Bangladesh, and such technological solutions do not appear to address these factors.

In the coastal areas, which are subject to periodic violent cyclones, concrete may find application for the construction of protective shelters. In such areas, which are generally inhabitable because of such severe environmental constraints, fishermen and their families are forced to live in order to earn a livelihood. Such a situation is the cause of serious tragedies. For this reason, the construction of some concrete shelters in strategic locations with external or government funding may provide respite during periods of disasters. In the present economic context of Bangladesh, the use of concrete, or even fired brick is prohibitively expensive for the majority of the rural populace, and cannot be considered for extensive application in the construction of residential buildings.

In the Grameen Bank housing project in Bangladesh (19), concrete floor slabs and columns were produced on site. C.I. sheet roofs were used along with bamboo mat walls. This was a credit program, where the loan recipients were compelled to use the project scheme. The recipients could not sell the concrete slabs and columns in the market after they received them, as they were too heavy to be easily transported. These building components were too large and could not be broken into smaller re-useable parts. In some ways this project is considered a success. But this does not represent a real solution, as cement is a scarce and expensive item in rural areas, and a scheme utilizing less amount of cement is required, to be within affordable reach to the rural poor with supporting aid or a credit scheme. Intermediate technology, in most cases, requires an accompanying credit/loan scheme, and can be successful only when the scheme is efficient and suitable for the context, which in many ways the Grameen Bank housing project appears to be. The pros and cons of such a mode of operation have to be seriously evaluated before it can be deemed feasible.

The alternative intermediate technology, using less cement, would be to cast concrete blocks on site, each with a hole for inserting a bamboo post in it. These blocks can either rest on the ground or be partially embedded in the ground for stability. The lower ends of the posts, which are to be inserted into the blocks, can be coated with a

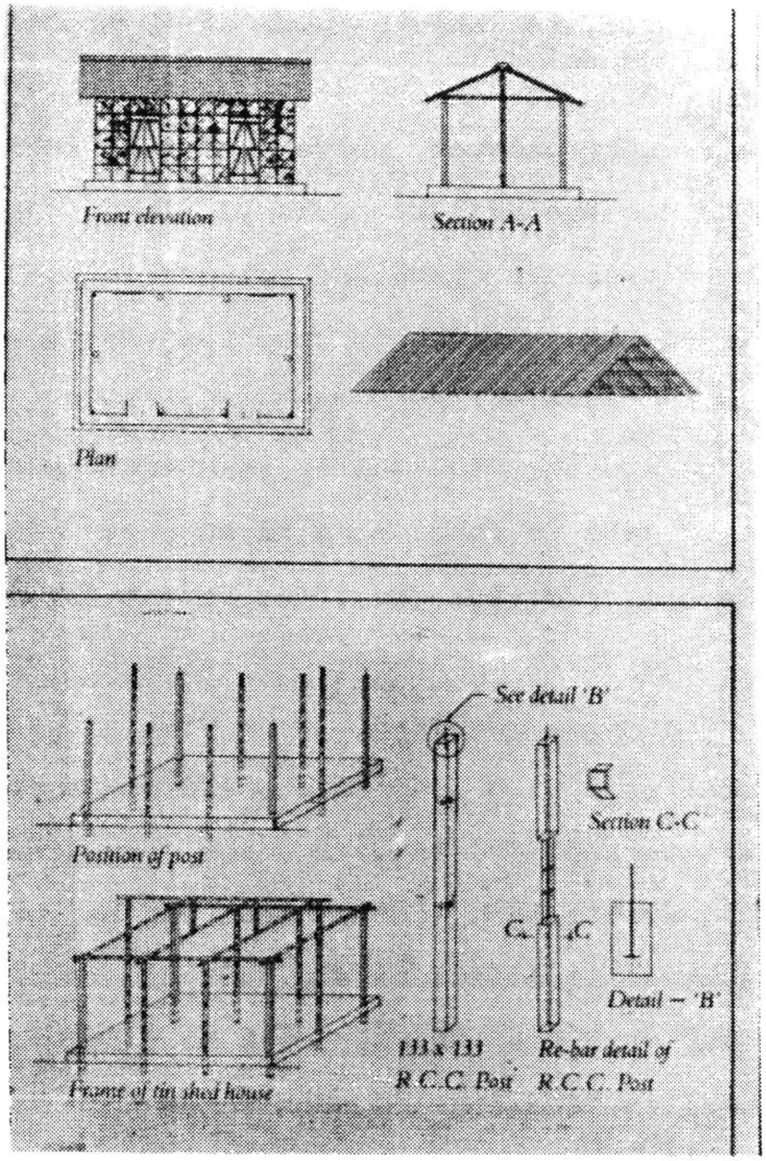


Fig. V.8. The Grameen Bank housing project in Bangladesh.

layer of bitumin. This way, the bamboo posts would be protected from ground water and termites, yet would be exposed as they traditionally are in Bangladeshi rural buildings. However, in the absence of bitumin, rainwater may seep into the hole in the block from above and stagnate inside, and may eventually affect the bamboo post. For this reason, it would be imperative to allow drainage from within the block. This can be accomplished by retaining a small opening, leading from the hole to the outside.

Instead of having a hole in the block, the other technique could be to have a vertical dowel, embedded into the block during casting. Bamboo posts being hollow, the bottom of the posts can be fastened to the dowel, the dowel being the male part and the bamboo post being the female. Short lengths of steel rebar can be used as dowels, or even lengths of split bamboo can be used to that effect. But the top portion of the bamboo dowels may wear out and it would be difficult to replace them, as the lower part would be strongly embedded in the concrete block. Therefore, steel rebars would prove to be more viable, due to their durability.

This is where lime-pozzolanic cement may find application. Instead of normal Portland cement, the use of such a cement would reduce costs greatly. As such cement hardens through prolonged contact with water, the blocks made of such cement would become quite durable through

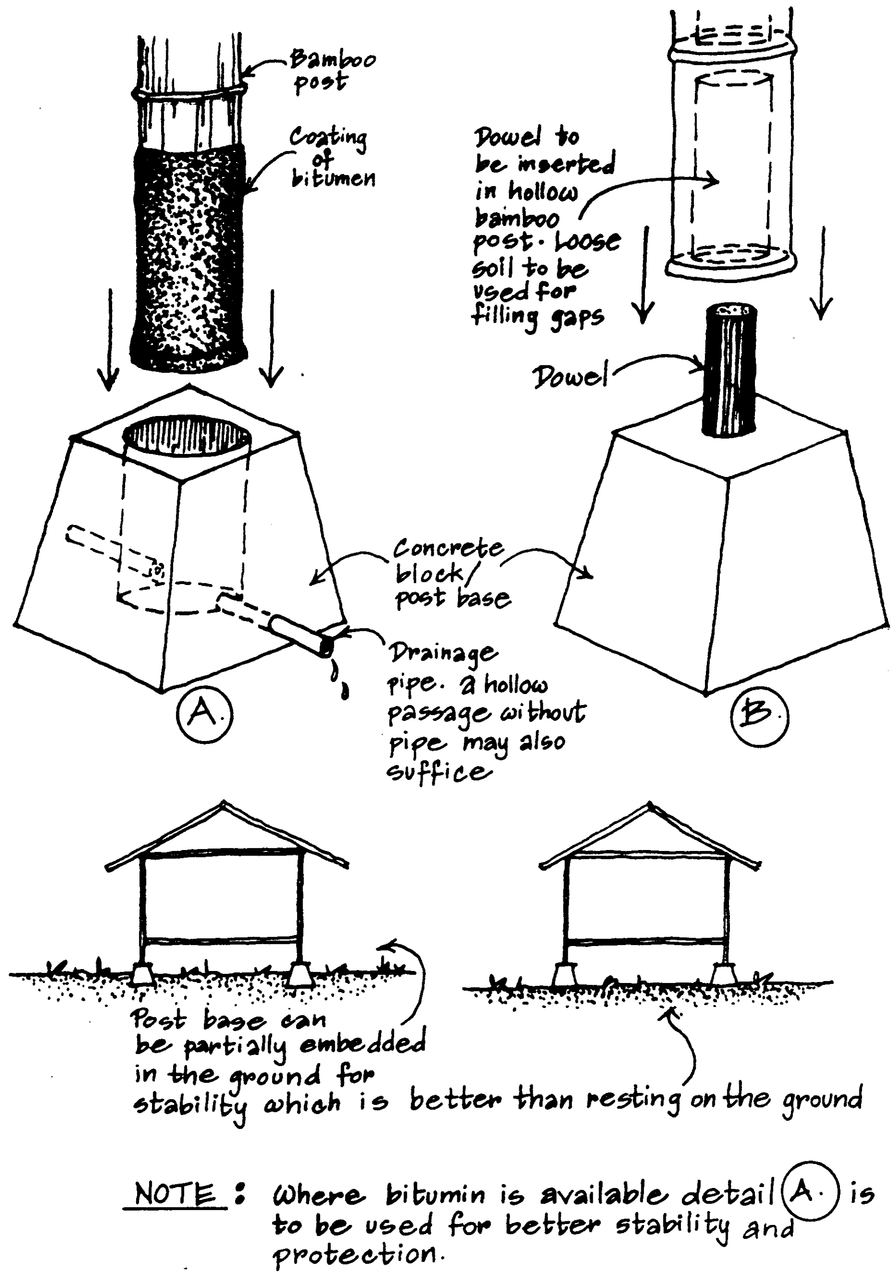


Fig. V.9. Concrete blocks for protecting bamboo posts.

exposure to the wet ground, so characteristic of flood prone Bangladesh.

Even such schemes may prove to be too expensive for most rural people, and may require an accompanying credit scheme. Steel and cement are extremely scarce and expensive items in rural areas. Their limited use in only small amounts and in very few parts of a building might allow improvement in the problem areas of the building.

It is an important exercise to reflect upon some of the other experiences as related to technological innovation in other parts of the world. For example, to cite one case,

> "ADAUA experience in West Africa has demonstrated that imported building technology, alien to the local life-style and building methods, takes time to be accepted and requires continuous training before it becomes a common method of construction for new users. It is particularly difficult when it is expected to take place on a large scale," (20)

This is an relevant factor to bear in mind throughout this whole discussion about the possibilities of improvement. Whenever possible, the traditional established building practices are to be respected and continued. Only in case of the most serious problems, a new method may be considered. The new method should not be one which is completely different from the traditional one, rather it should be based on the traditional one, with the intention of improving it.

There is often a wide gap between the environmental adaptation techniques of the poor and the proposed improvement techniques of well-meaning professionals. The following phenomenon is in some ways indicative of this gap: In many cases, a separate platform made of bamboo is constructed in flood-prone areas, and the occupants of the buildings seek refuge there during periods of high floods:

> "a platform of bamboos is then constructed at one end of the hut and upon this the family sit and sleep while they must wade through the mud to reach the door." (21)

This is certainly not an ideal solution, specially according to "Western" standards, but may be suited to the socio-cultural conditions of the rural populace of Bangladesh. Every time we seek to replace an older tradition with a new one, careful evaluation in all regards must be conducted before it is implemented. The significant fact that is evident from this discussion is that, in many cases, there is really no serious need to develop new foundation construction techniques for the rural residential buildings. Some of the local solutions are ingenious, and are tailored according to the needs and capacities of the people who have developed them.

In spite of my hesitancy in embracing any drastic change in the current foundation construction techniques for residential buildings of the rural poor, a case can be made for an improved foundation for rural institutional buildings, such as health care facilities, schools, post offices or religious buildings. Such buildings are usually funded by the government or external agencies, and it is not necessary here to expect poor people to fund changes implemented from the outside. Through time, the institutional buildings may influence the local residential building patterns, but this should be left to the decision of the users, and should not be an external concept imposed on them.

In the case of the foundations for institutional buildings, I would recommend the application of lime-pozzolanic cement and stepped brick foundations and brick plinths. The reduction in the use of Portland cement will certainly reduce costs, and will utilize locally available materials with maximum efficiency. Instead of constructing cement paved floors, the use of bricks for the floor surface may be practical. Damp-proofing courses have to be provided below the brick floor, as is conventionally done with bitumin in concrete floors. The use of lime-pozzolanic cement for the damp-proofing course may also be considered, instead of bitumin, which in general is more expensive. This course would also allow the bricks to form an even floor surface, which would not happen if the bricks are laid directly upon the earthen floor.

V.2.2. Walls:

These are the parts of the building which utilize earth to the largest extent. As I have identified four main types of vernacular wall building techniques, I will discuss these four types and the possibilities of improving them.

a. The layering technique is used widely for residential buildings in Bangladesh. Examples are mostly located in relatively dry areas, where they provide very comfortable living environments. As observed by Hasan,

> "Well built and properly maintained mud houses were seen in different parts of Bangladesh during field trips in connection with the case studies. Even in areas of heavy rainfall such as the central and southern part of the country, there are very old mud houses in quite good condition." (22)

Broad roof eaves protect the earthen walls from rainwater. The erosion caused by wind driven rain is amended annually by the residents, in general by the female members of the household. Maintenance is done by replastering the walls with a mixture of mud slurry and cowdung, which acts as a binder. The earthen plinth requires more maintenance than the walls, as it is exposed to accumulated rainwater on the ground during the rainy season. This maintenance activity is culturally rooted, and the good condition of these houses, as described by Hasan, are due to their design and care, which is a reflection of the culture and an adaptation to environmental conditions.

In some cases the earthen walls are quite thick, as mentioned earlier in Chapters II and III. But this is so in the relatively drier areas, where there is a need for adaptation to the diurnal temperature swing. In such areas, often daytime activities are carried on indoors which is cooler, while many nighttime activities are carried on in the outdoor courtyard; often in the summer, the family sleeps in the verandah or courtyard. In areas which are more humid, the earthen walls are thinner to provide comfortable indoor living conditions.

Therefore these earthen buildings represent a highly evolved form of construction, which respond well to the environmental conditions, and utilize locally available materials and skills. Yet this kind of architecture is gradually declining in use and is being replaced by architecture based on industrialized building products. This is an issue of human choice. The traditional earthen construction has popular connotations of being primitive, underdeveloped and rustic, whereas the buildings built out of industrial materials are viewed as modern, even though they do not perform well climatically and bear no relation to the availability of local materials and techniques.

There is then a sound argument for the preservation and improvement of the old building traditions. These are in general tremendously difficult tasks, and involve a gradual reorientation of social values. Education of the rural population has to be achieved along with increased cultural awareness. With institutional redirection, the education system might place emphasis on cultural values. According to Spence and Cook there is a slow change in awareness in many developing countries (23), and hopefully such changes will also come about in Bangladesh.

The layering technique is effective in the case of residential buildings, which are small in size and where the broad roof eaves efficiently protect the earthen walls from rain. Also regular care and maintenance by their owners helps to assure the durability of the buildings. But the application of the layering technique to build walls of institutional buildings is a different matter. The larger size of institutional buildings would make it necessary to also have larger roofs with broad slopes. In that way the roof would be the over riding part of the structure. At this time, there is a lack of suitable roofing materials in Bangladesh, so that a large roof would not only be quite expensive, it would also require a sturdy supporting structure, which may require considerable building skills.

Constructing residential buildings of smaller size is manageable with the layering technique. However, constructing larger buildings may prove to be difficult as there are no existing traditions and skills for doing so in the layering technique. Also larger buildings entail much thicker earthen walls, which are not suitable for the climate. Such buildings require frequent maintenance, and institutional buildings would require external initiative for maintenance - which may easily lead to neglect and deterioration.

I propose therefore that the layering technique should only be utilized in the case of residential buildings and not for constructing large institutional buildings. For institutional buildings other forms of construction have to be considered.

b. Walls built with large earth blocks (see Chapter II) have similar characteristics to walls built in the layering technique in many ways. This is also a highly refined construction technique. Nevertheless, the addition of a small proportion of lime to the soil mixture, about 6-14 or 20% while forming the blocks, will greatly increase the strength and water-resistant quality of the blocks. The amount of lime to be added depends on the type of soil; generally, for sandy soils, the amount of lime additive required is more.(24) In this case it is important to grout the gaps between the blocks, after shrinkage has occurred, with mortar of the same constituents as of the blocks, of slightly weaker consistency. In this way future cracking can occur in the mortar joints and not in the blocks. Cracks in mortar joints can be repaired by consequent grouting, but cracks in the blocks may result in serious structural damage to the building.

c. As has been discussed earlier (chapter II), the use of sun-dried bricks is restricted to certain physiographic areas in Bangladesh. The need for dry ground to make the bricks and dry them for a prolonged period necessitates the location of such production in dry or hilly areas. The use of sun-dried bricks is mostly limited to residential buildings, some of which are of excellent quality; two-storied buildings built with sun-dried bricks can be seen in some areas. As with the layering technique, this mode of construction is also going through decline and attention should be focussed on ways to keep the tradition alive.

Sun-dried bricks have tremendous potential for application in institutional buildings. In areas of high rainfall the exterior wall may be constructed out of fired bricks to ensure protection, but all interior walls can be built with sun-dried bricks. Sun-dried bricks utilize solar energy for attaining their hardness, and their use would limit the quantity of the energy intensive fired bricks needed.

Many institutional buildings are subject to regular wear-and-tear. The use of the inexpensive sun-dried bricks can be justified on this ground, in comparison to other expensive materials, such as cement blocks, fired bricks or C.I. sheets. Their maintenance is also less expensive, as most repair work can be done with local earth and lime. Hence, this involves the possibility of a reduction in overall neglect of the structure, as the maintenance is simple and inexpensive.

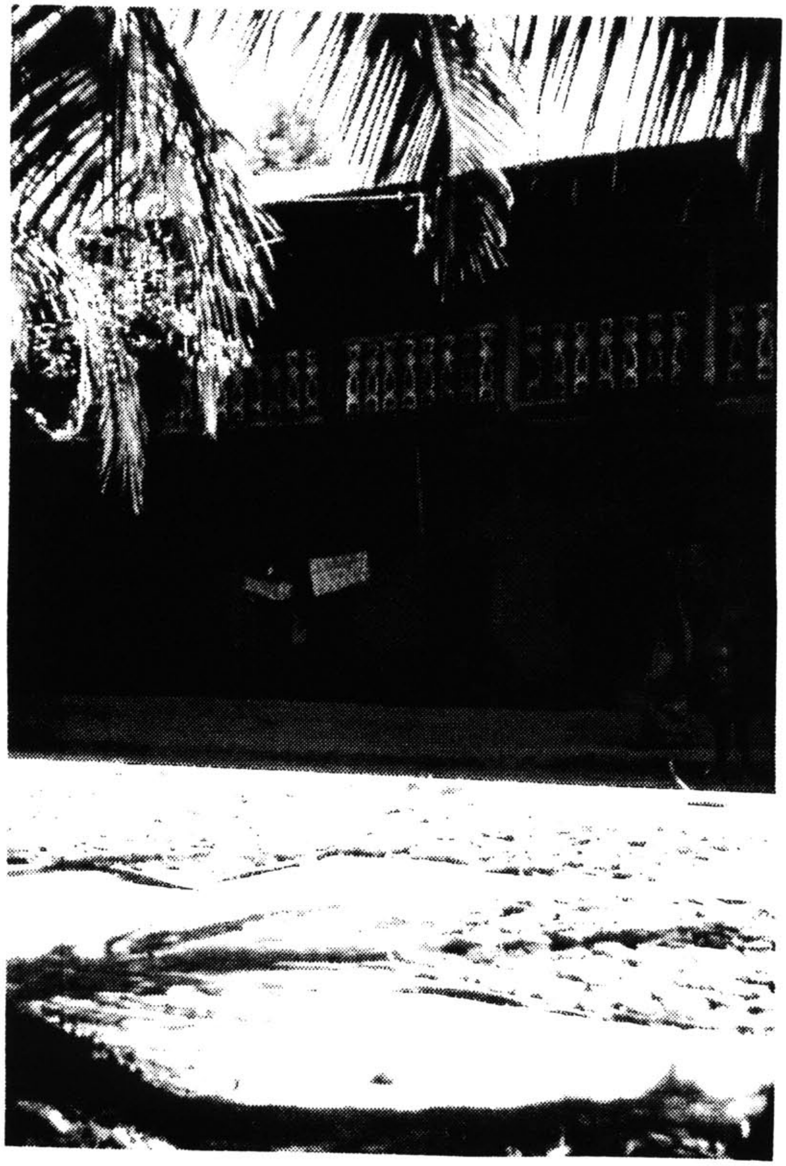


Fig. V.10. A two-storied house of sun-dried bricks and plastered with mud and cowdung, in the hilly region of Chittagong.

A combination of sun-dried and fired bricks can produce results which are harmonious in terms of color and texture, as these two products have similarities with regard to those qualities. These two products are also mutually compatible in terms of bonding, similarity of finishing and maintenance. Both are products of the same material, earth - the bountiful, alluvial deposit.

c. Walls constructed out of bamboo mats are the most common type in Bangladesh. Their use is prevalent in the coastal and deltaic regions, which comprise the major part of Bangladesh. In some areas, reeds and jute sticks are also used for building walls, but generally this technique is more prevalent in the ancillary buildings, such as stables, granaries, outhouses etc. Walls constructed out of bamboo, reeds or jute sticks, create the real problem of rural architecture in Bangladesh. First I will identify the main problems with this kind of construction and then propose solutions that address those problems.

As Hasan has noted,

> "The bamboo or reed panels are usually quite vulnerable to attack by insects and water. Also the bamboo framing for the superstructure often fails to adopt proper structural principles for strength and stability." (25)

That is, he has identified two main problem areas. The first one is that the untreated and exposed bamboo mats (or reed, jute sticks etc.) are susceptible to decay due to frequent and prolonged contact with water from rain and

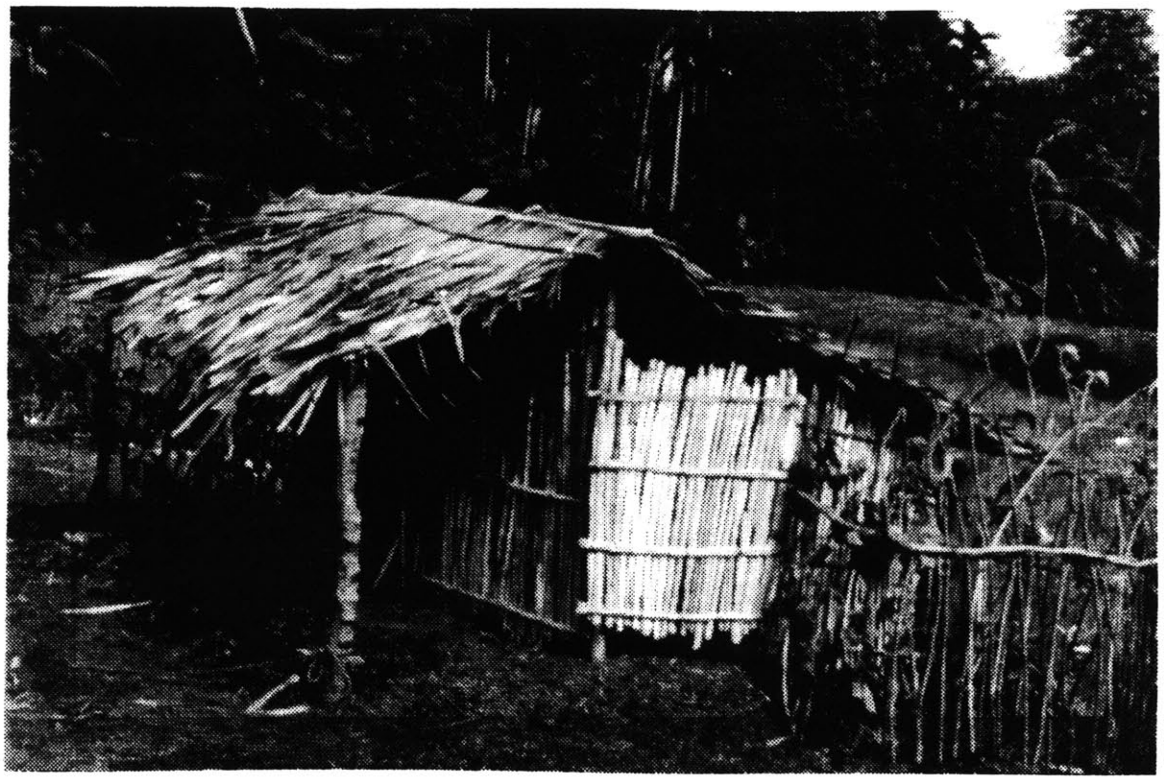


Fig. V.11. Jute sticks or reeds are used for constructing ancillary buildings.

floods. Attack by termites and micro-organisms is also a major cause of decay.

Bamboo posts can be treated in ways mentioned earlier, but that would not be an applicable treatment for walls. As I had mentioned in chapter II (section II.3.2.), the bamboo mats or reed/jute sticks are plastered in some areas with a mixture of cow-dung and clay. The cow-dung functions as a binder, albeit a weak one, and the local alluvial clayey soil is utilized for its plasticity in the daubing process. In many cases, only the lower part of the wall, which is more vulnerable to decay, is plastered. This is an attempt to protect the earthen panels from water and insects. However, this form of daubing tends to be washed out after some time, and requires frequent maintenance, probably the reason why it is not more widespread.

The addition of a small proportion of lime to the soil mixture increases its durability and also makes it workable. In the case of very sandy soil, up to 20% of lime additive may be required. Norton has written that generally the amount of additive varies from 3-10% by dry weight for most soils (26). As mentioned earlier, lime is a widely available material in Bangladesh, and the practice of lime stabilization would be generally affordable. Also lime works as an effective stabilizer on clayey soil, a type that is characteristic in the delta region (27). Addition of pozzolans, to the lime stabilizer that is powder from burnt clay products, or "surkhi" as it is locally known, greatly enhances the strength of the daub plaster. This type of technology would be based on locally available and affordable materials and practices, and such, improvement within the existing framework of the context would have a greater possibility of acceptance.

The second problem area is that the thin bamboo mat walls do not have the strength to resist the strong winds and stormy weather of the coastal regions. M.P. Chrisholm was a disaster relief worker in Bangladesh, and it is his observation that,

> "in cyclonic winds, the roof is not carried far and usually collapses to the ground due to the walls giving way first. In this respect the posts and lower parts of the bamboo walls are the elements that are the most susceptible to deterioration from termites, water etc., and as such present the weakest parts of the house." (28)

Applying plaster to the bamboo panels provides additional stiffness to the walls and hence they would be better able to resist the cyclonic winds. In any event, plastering would protect the bamboo mats, and in extreme rainfall conditions, only the plaster would be damaged, which could easily be renewed.

Chrisholm also found a lack of cross-bracing techniques (29) in the bamboo frame structures. In spite of the high development of bamboo technology in Bangladesh, this is certainly a deficient area that needs to be addressed. The tensile properties of bamboo framing make it suitable for

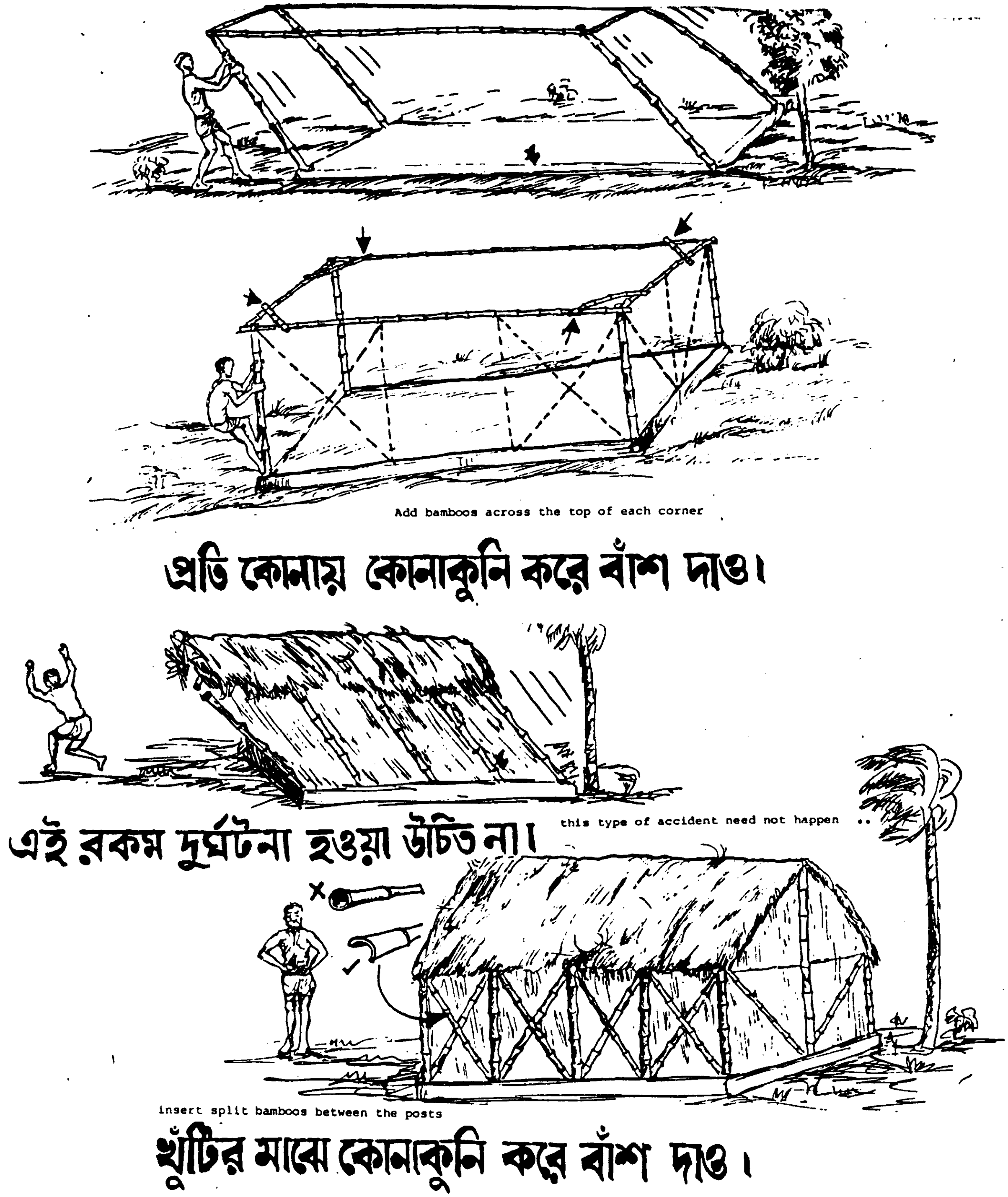


Fig. V.12. Cross-bracing techniques for improving bamboo structures.

windy regions, and provision of proper cross-bracing can greatly enhance its resistance to the frequent cyclonic winds. Chrisholm has suggested ways to provide cross-bracing to the weak parts of the bamboo frame. The principle of cross-bracing is actually accepted in local practice, and can be seen in bamboo bridges and bamboo doors, therefore its introduction in the weak parts of the bamboo frame of dwellings would not be culturally alien.

Traditional wattle and daub construction as built in many parts of the world is of two main types. One type is where it usually consists of a skeleton frame of woven wattle or bamboo/timber laths upon which the plaster is applied. The other type consists of two parallel vertical wooden/bamboo frames, the space between which is filled with earth.

The daubing of bamboo mat walls in Bangladesh is somewhat different from these two techniques. Here plaster is applied as a protective measure upon diagonal or square plaited bamboo mats. Such mats are used in many places without any plaster, in which case the mats form the walls of the building.

The other prevalent technique of wattle and daub in Bangladesh consists of a wall constructed out of lengths of split bamboo, or jute sticks, aligned vertically or horizontally alongside each other, and then plastered (see Fig.19). The use of jute sticks can be observed more in the

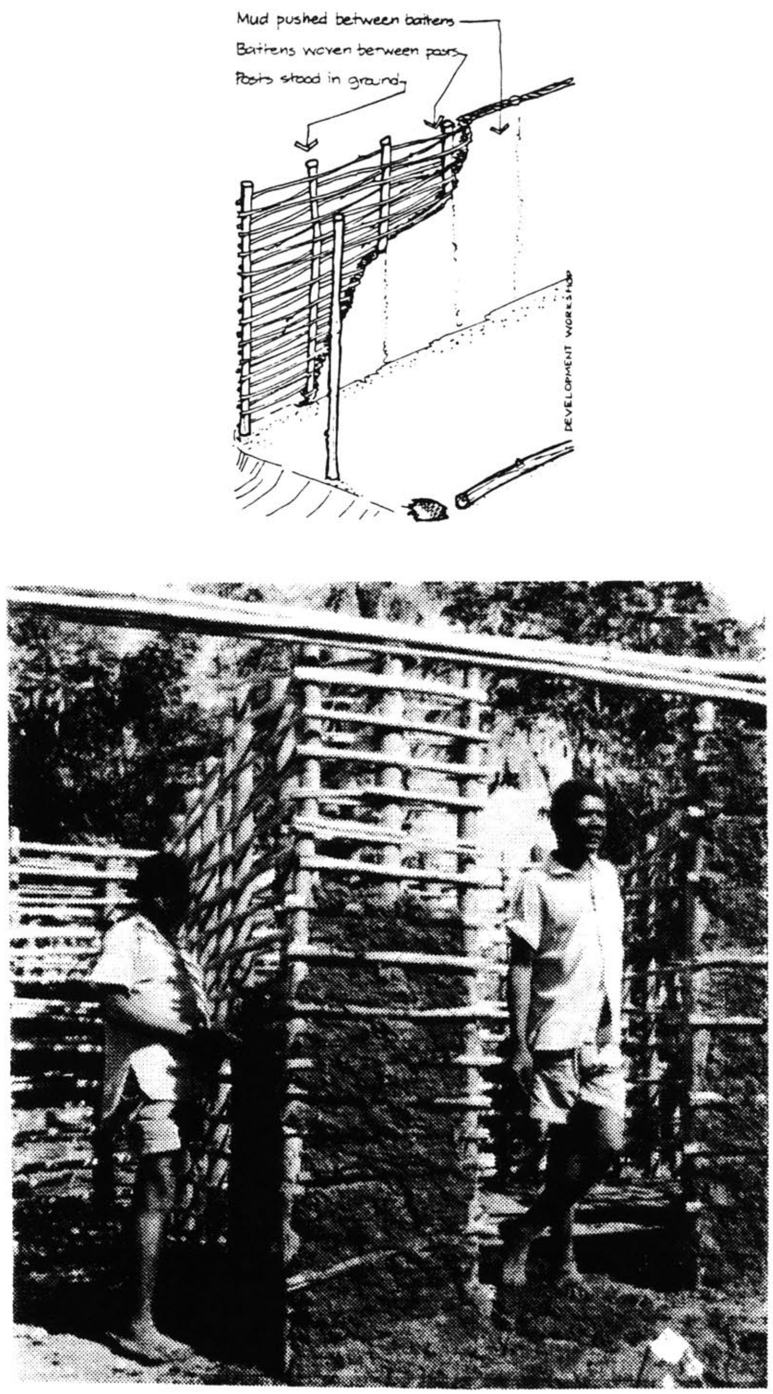


Fig. V.13. Two types of wattle and daub: above, a skeleton of woven wattle mud-plastered, lower, two parallel frames with mud infill.

ancillary buildings as it is less durable than bamboo. These techniques have been dealt with in more detail in Chapter II.

In the case of application of improvement techniques with lime/pozzolanic plaster, these regional variations have to be considered. Local practices would provide indications for the amount of plaster to be applied, the availability of suitable building soil and stabilizers, the appropriate building season and other similar factors. Consequently, the improvement techniques would be introduced in specific centers and gradually spread outward to improve bamboo buildings of a larger locality.

Regarding affordability, the experience of Witold Rybczynski can be related:

> "Earth building exhibits varying degrees of complexity, sophistication, and cost. It is particularly cheap when used as an infill with bamboo or wood." (30)

This would certainly be the case in Bangladesh. All the ingredients of the wattle and daub construction are widely available in Bangladesh. Bamboo grows extensively in the tropical climate and some varieties of bamboo are extremely fast-growing, and hence represent a renewable supply. Bamboo technology being highly evolved in Bangladesh, the investment in training and development of local skills would be negligible.

The prevalence of the wattle and daub technique in other hot-humid areas of the world, such as in Sri Lanka and

Panama (Chapter III), is an indication of its suitability for such a climate. Hot-humid regions allow the growth of trees which supply material for the extensive frame of the structure, making wattle and daub a suitable technique, which is not the case in arid areas.

The application of the wattle and daub technique cannot be extended to institutional buildings, for similar reasons to those which limit the use of the layering technique to residential buildings. The need for frequent maintenance make this technique generally unsuitable for public buildings, as such buildings are often prone to neglect and low maintenance in Bangladesh.

V.2.3. Roofs:

This is one of the most problematic areas of rural architecture in Bangladesh. In chapter II, I have discussed the advent of corrugated iron sheets for use as a building material, both for walls and roofs. I will not discuss flat roofs in detail here, as they are in general climatically unsuitable for Bangladesh. Flat roofs are seldom seen in the rural areas. Prior to the introduction of reinforced concrete roof slabs, which are now used for the roofs of the affluent in urban residential buildings and also in institutional buildings, some of the British colonial buildings also employed flat roofs. In this type, steel I-beams were used to support the roof which was constructed out of lime concrete. This type of construction has become obsolete now, due to the advent of reinforced concrete roofs, and the existing buildings with this type of roof have become serious public hazards due to lack of maintenance. Such a roof collapsed in Jagannath Hall in Dhaka University in 1985, and caused the death of more than three hundred students.

Even though I have discussed Bangladeshi rural roofs in chapter II, here I will outline them to explore possibilities of improvement. As mentioned earlier, the topic of roofs in rural areas of Bangladesh is a specialized area of study due to the complexity of the changes that are occurring and the severe lack of available solutions. Therefore, I will deal only briefly with this subject here.

In rural areas of Bangladesh, at present, there are mainly the three following types of roof:

a. Thatch: This is an indigenous material for roofing used continuously from the earliest times in Bangladesh. Various different types of leaves and thatching techniques exist according to the region. The most common types are rice straw, used more in the drier areas, and coconut palm leaves, prevalent in the coastal areas.

While the art of thatching is highly developed in Bangladesh, in recent years, this art has experienced a gradual decline and is being steadily replaced by C.I. sheet

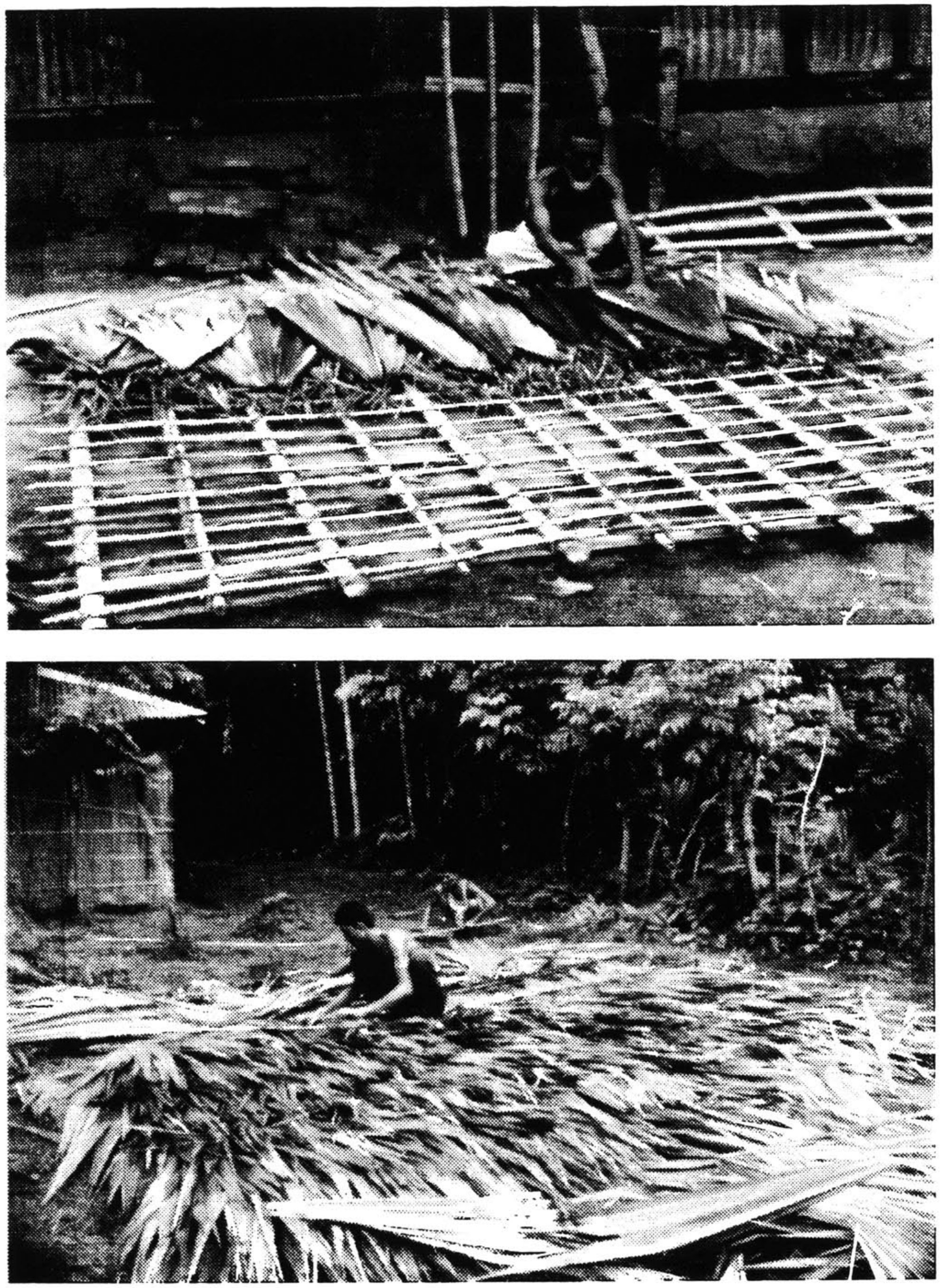


Fig. V.14. Thatchers at work in Bangladesh.

roofing. Only the houses of the poor and ancillary buildings have thatched roofs today, and whenever it is possible for the owners, they replace the thatched roofs with C.I. sheet roofing.

Spence and Cook have written:

> "All forms of thatch are combustible, and all are prone to organic decay and insect attack. Various methods of chemical treatment have been developed to reduce these problems, but so far no cheap permanent technique has been developed." (31)

Organic decay is the primary reason why thatch is considered as an inferior material. As observed by Hasan, "Generally such roofs have to be re-done once a year, especially the covering" (32). The regular maintenance of thatch is associated with a primitive and rustic approach to life, and also has the connotation of poverty; people who cannot afford modern roofs have to settle for this perishable material, which regularly wears out.

Insect attack is the other problem with thatch. Apart from thatch itself being eaten out by termites, it provides a nesting ground for various types of harmful insects. The "chagas" disease, so prevalent in South American thatch roofs, does not exist in Bangladesh. However, the insect pests can be a source of agonizing irritation for the inhabitants of a thatch roofed house. Thatch also provides a daytime hiding space for mosquitos, which spread malaria and filaria in rural areas.

Spence and Cook have discussed some of the experimental protective treatment methods for thatch (33). The use of chemical preservatives poses a problem because of its inaccessibility, and in some cases, the high cost. Also these chemicals tend to get washed out of the thatch due to rain. The application of a coating of earth on the thatch is a customary preventive practice in some areas, and stabilized soil has also been experimentally used in some cases. But thatch and soil do not form permanent bonds, and this form of treatment tends to get washed out by rain too, thus requiring frequent maintenance.

The use of plastic coating as a protective treatment for thatch may be considered. However, such a technique has not been properly developed yet, and may pose difficulties in terms of application skills and costs. Therefore, investigation of research into prolonging life of thatch by plastic coating have to be conducted before it can be considered for application.

In some parts of northern Europe, there are durable varieties of reed plants which are used for thatching. It may be possible to introduce such reeds in Bangladesh, by spreading seeds of those plants in marshy areas. Allowing its wild growth to flourish may eventually result in its application for an improved quality of thatching by the rural inhabitants. However, such a practice may have detrimental ecological consequences on the indigenous flora and fauna. For this reason, botanical advice regarding this

Fig. V.15. Durable thatch roof in northern Germany.

concept should be considered to assess its suitability. Whether such varieties of reed plants would grow in the climate of Bangladesh is also a major factor to be considered.

In recent times in Bangladesh, the use of polyethylene sheets sandwiched between thatch or bamboo mats have been introduced. Oxfam, Concern and World Vision are the notable organizations who have implemented this technique in disaster areas, with its subsequent growth in popularity (34). This type of roofing has an extended lifetime and also provides adequate protection from rain. But polyethylene is an imported material and also the variety currently being used is basically a synthetic product. The transition from the use of natural, locally available building materials to synthetic, imported, mass produced industrial materials may represent a leap into a unknown future of a threatened environment. In the absence of suitably durable roofing materials, these kinds of solutions are bound to proliferate and influence human choice. If such solutions are destined to gain in popularity, research and public initiative have to be directed to develop resources for the application of plastic products which can be recycled. As mentioned earlier, recycling has tremendous potential in a country like Bangladesh, and orientation of public policy in this direction might yield results which do not threaten the future environment.

So far the application of thatching has been limited to residential buildings, and unlike other parts of the world (such as Samoa, for example), no community or institutional buildings make use of thatch in Bangladesh. Most institutional buildings, by their nature of being distant from community participation, is often an unsuitable building type for the application of such a material which requires regular maintenance. However, as I will discuss later, institutional buildings such as the women's family planning center at Bhollobpur, Bangladesh, utilized thatch with the result that it was more acceptable to the rural people. Therefore, public initiative geared towards adequate maintenance may allow a perishable material like thatch to be used in institutional buildings, resulting in the creation of culturally appropriate architecture.

b. Fired clay tiles: As mentioned in chapter II, this type of roofing has gone through a decline in Bangladesh due to the mass migration of Hindu potters. Tiled roofs are used in the western part of Bangladesh, adjacent to the Indian border. Just across the border, there is a wide prevalence of this type of roofs.

Fired clay tile roofing is very well suited for the climate in Bangladesh, and utilizes local resources, that is earth, for its production. However, its production is an energy-intensive process, and severe deforestation in some

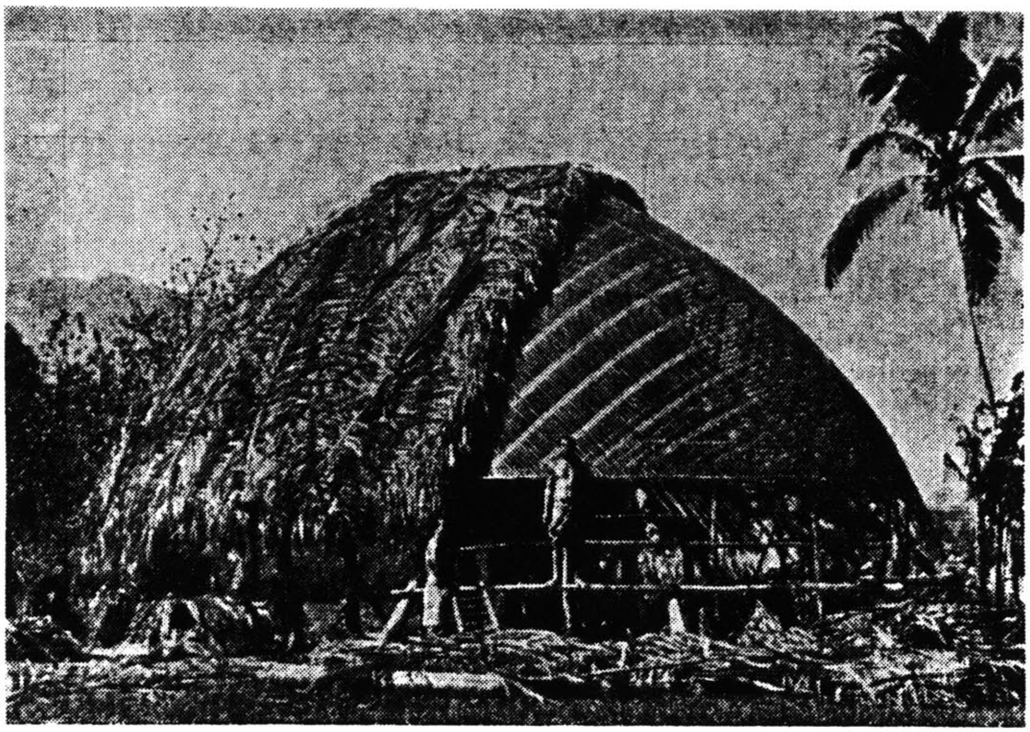


Fig. V.16. Chief´s house: an institutional building with thatch roof in Samoa.

parts of Bangladesh may make this roofing material an inappropriate one at this time. Proper re-forestation initiatives may eventually make more wood available as fuel in the future, in which case the production of fired clay tiles might be a justifiable enterprise. At present, factory-manufactured clay tiles are available in urban areas, but they constitute an expensive commodity which only some affluent members of the urban population can afford.

Bangladesh has a large variety of pottery products, which are used in the daily life of the people. Unfortunately, clay tile is not one of the items being currently produced. The introduction of its production would have to be accompanied by the training of local skills for its installation in roof structures, as such skills have disappeared from most regions.

Whether the re-introduction of clay tile roofing is a viable enterprise is a debatable issue. Such a mode of roofing may have advantages in some areas with suitable soil, energy resources, local initiative and pottery skills. Depending on the region, the overall costs and benefits have to be evaluated. Clay tile roofing certainly has a practical application in institutional buildings. Tiles had been extensively employed in the institutional buildings of the British colonial period. Again, institutional application can serve as a method for this re-introduction for use in residential buildings.

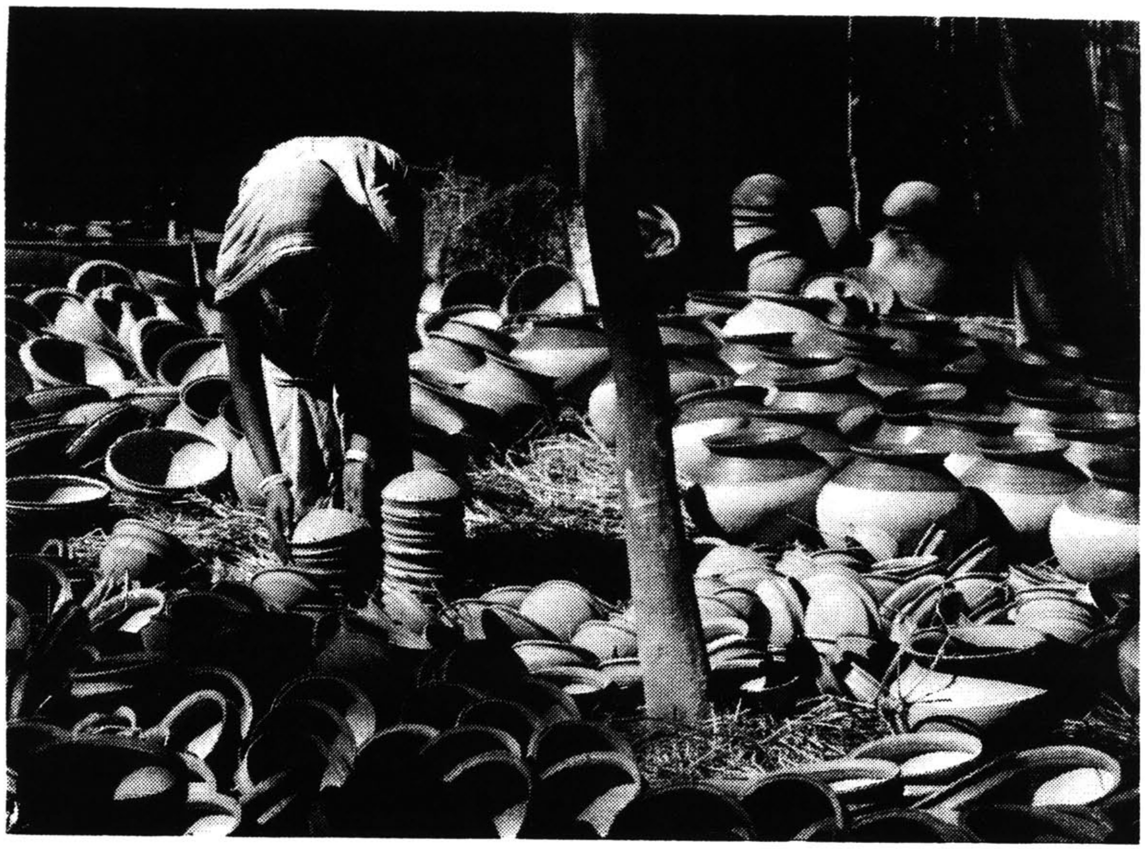


Fig. V.17. Bangladesh has a variety of pottery products which are used in the daily life of the people.

c. C.I. sheets: This material, which stands on the crossroads of academic/professional anathema and mass popularity, has been extensively discussed in Chapter II. I will not deal here with the unsuitable qualities of C.I. sheets for the rural environment of Bangladesh, and instead of denouncing them, I will play the role of the devil´s advocate, to explore if at all this material can be used in a viable way.

As I mentioned earlier, C.I. sheets have gained tremendous popularity in most parts of Bangladesh. In general, the high quality sheets are affordable by the rural affluent. However, to cater to the needs of the poor many varieties of low-grade sheets have been made available in the market. Their resale value and ease of dismantling make them desirable to the poor.

To reduce the disadvantages of C.I. sheet roofs, such as thermal and noise vulnerability, and also to conceal the demoralizing appearance of the rust-coated sheets, they are covered in many areas with a layer of thatching material like straw or palm leaves. In such areas, the roof is often used for the cultivation of squash and cucumber plants, which by their nature being creeper vines, require a rough surface for the intertwining growth. The layering of the smooth surface of C.I. sheet roofs with palm fronds or straw enables the growth of such plants, which also add to the protective qualities of the thatch layering.

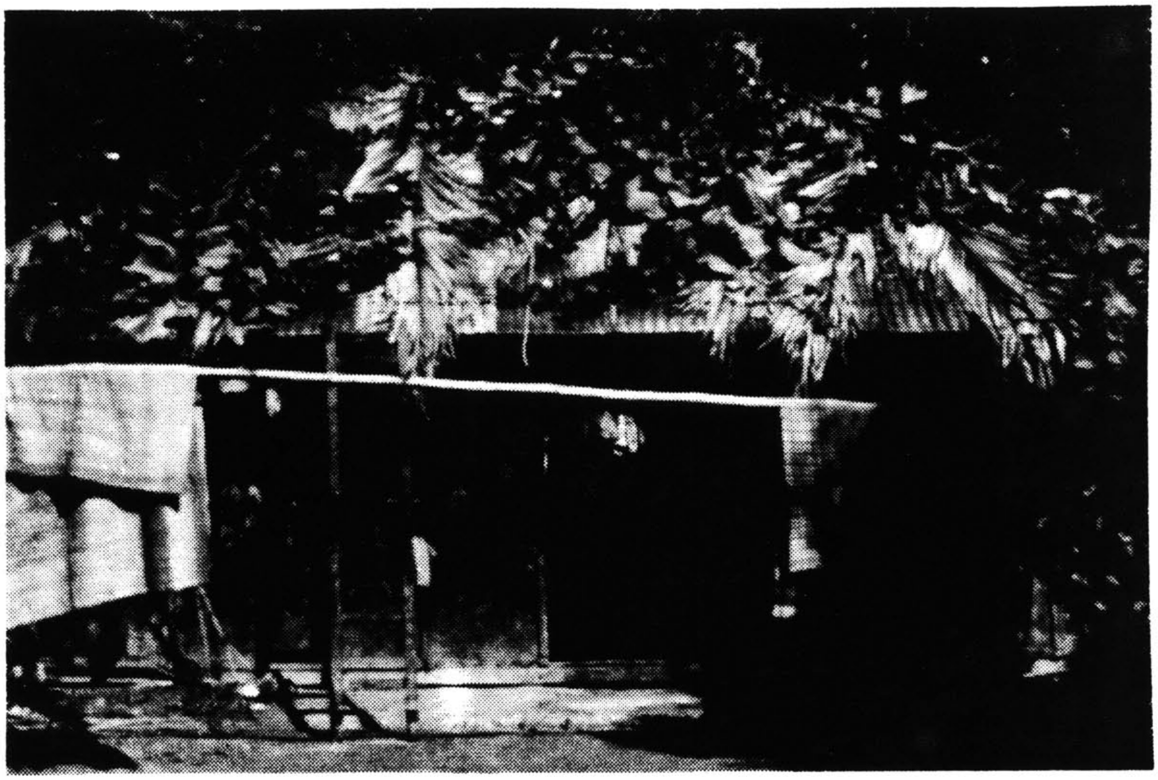


Fig. V.18. C.I. sheet roof covered with thatch is used for growing vegetable-bearing creepers.

This, then, represents a transformation of a disadvantageous material into a more suitable form. Such a practice should be encouraged as much as possible, in the event of the popular preference of C.I. sheet roofing. Ways to improve this concept can be devised, such as improved and thicker layering of thatch and ways of providing strong binding of the thatch to the C.I. sheets. For example, layering the thatch covering with earth will protect it and also supply growth nutrients to the vines.

The ingenuity of the rural people in creating such a solution is an indication of their resilience and resourcefulness. With some encouragement and assistance, this ingenuity can flourish and enrich the state-of-the-art of Bangladeshi rural architecture.

V.3. RURAL BUILDING TYPES:

Improvement of rural architecture is customarily associated with the improvement of housing. This is probably due to the fact that, in former times, housing was the primary building type in rural areas. Religious buildings, and to some extent commercial buildings such as shops, restaurants etc. were the next building types that evolved in rural areas. However, in the context of the present age the need for other socio-economic functions have given birth to the evolution of various other building types. Increased communication links in the rural areas have not only made these new building types necessary, but in many cases imperative. Some of these buildings are related to public and administrative functions, while others relate to private enterprises. Here I will discuss these latter rural building types and explore the possibility of their improvement using applications of earth as a building material.

V.3.1. Schools:

The literacy rate of Bangladesh is about 24 % (35). This means that more than 75 % of the population of Bangladesh cannot read or write. In such a context, it is necessary to introduce educational opportunities for this large segment of the population. The purpose of education would be:

a. To enable people to fulfill their role in society.

b. To enable them to obtain employment.

c. To allow them to enrich their own lives. (36)

Various theories on education indicate its purpose along these lines. In former times in Bangladesh, religious and non-formal education served adequately to provide opportunities for people to carry out the social functions mentioned above. However, in the present day context, factors such as increased population, the need to engage in international trade and the necessity for greater production in many fields, among many other factors, require a wider availability of educational opportunities, which are secular and to some extent, formal.

There are criticisms of this approach to social change. Writers like Ivan Illich (37), for example, represent the ideological stance that mass education will transform society in ways that are similar to the development of society in industrialized countries. In any case, formal education introduces a level of complexity in the simple, straightforward life of rural people, which may disrupt their previous lifestyle.

Nevertheless, the creation of opportunities for education does not imply that they have to be based on a role-model developed in industrialized society. Elements of Bangladeshi non-formal education can be incorporated into formal institutions. Education can be oriented to develop vocational skills, as well as intellectual abilities, which can contribute to Bangladeshi society. To cite a simple example, education of farmers might allow them to make a choice between imported fertilizers which are harmful to the environment and those which are benign.

The writings of Michael Todaro (38) can be referred to about the role of rural development in the less developed countries. Critics of Todaro say that he places undue emphasis on the role of rural development, but that is not the main issue here. He has provided directions for rural development based on the attempts in this regard in many less developed countries. In the field of education, past effort has been directed towards producing qualified personnel with "Western-oriented" education, without adequate employment opportunities for them. This has eventually led to the need for reform to provide education with more potential for application:

> "Revised curricula, adult education, agricultural and vocational instruction, and leadership training programs are some of the specific reforms being tried in various countries." (39)

I will not stretch the argument regarding the need for wider educational opportunities. I will simply stress the emerging need for such opportunities. More schools need to be built in rural areas, as they are already being built, and the role of an architect would be to utilize local resources in these buildings. Unfortunately, many rural schools are being built with materials like C.I. sheets, which are climatically uncomfortable and hamper the educational environment.

As mentioned earlier, sun-dried bricks have a great potential for use in the construction of interior partitions in school buildings. The exterior envelope can be constructed out of local fired bricks to resist deterioration, and lime-pozzolanic mortars can be used. Various forms of bamboo screens can be utilized for adequate cross-ventilation in different parts of the building. The construction of schools on a raised plinth, or a high

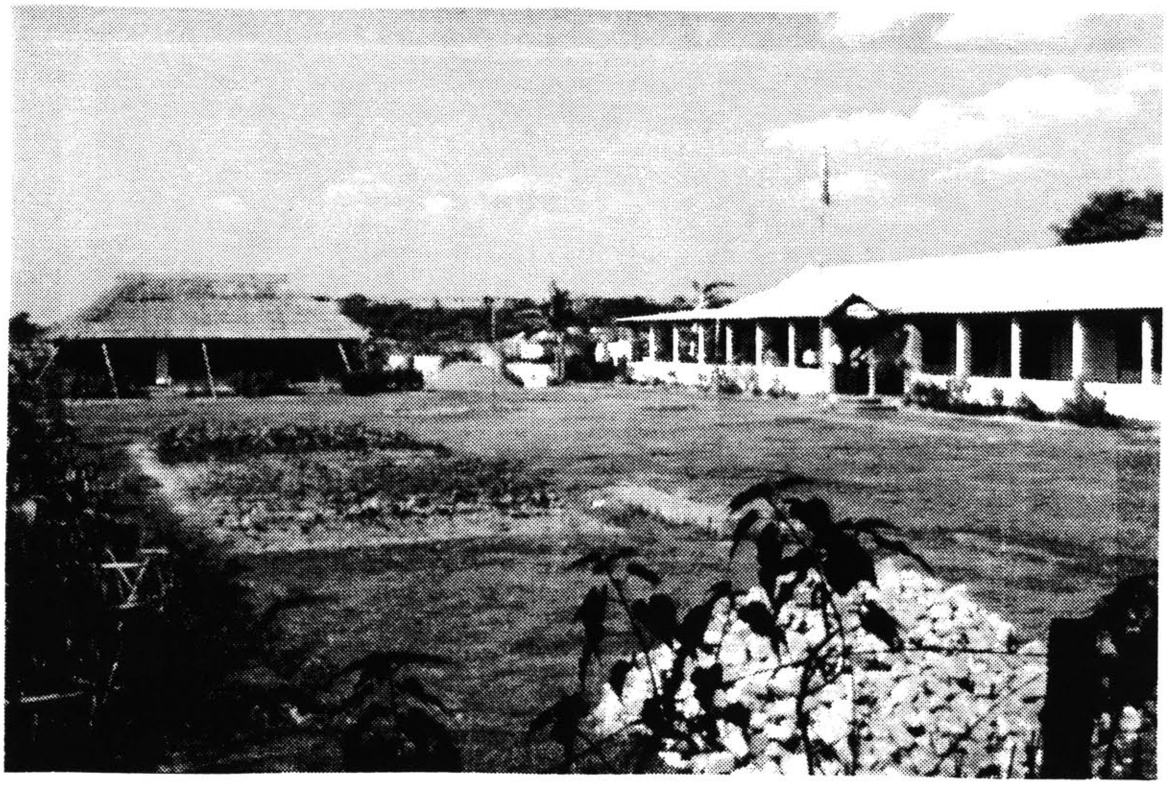


Fig. V.19. A C.I. sheet-roofed school in Bangladesh. Note the old thatch and bamboo building, which was the previous school building, now almost abandoned.

Fig. V.20. The use of bamboo mats as interior partitions in schools.

earthen mound can effectively allow them to function during the flood season.

Schools are in general funded by external agencies or the government. This funding can be utilized to develop indigenous materials for use in the school buildings, to make the most efficient use of the limited funding. More technically appropriate schools can be built in this way, instead of a few grand ones.

V.3.2. Health Care Facilities:

The increased population in Bangladesh has created the necessity of building health care facilities in rural areas. In former times, the village "medicine-man" could cater to the health care needs of the smaller rural population. But the present day population has expanded beyond the ability of the simple village "medicine-man" to provide care, and hence the need for institutional health care facilities.

However, this does not necessarily entail the application of "Western-oriented" methods of health care. Todaro has discussed the advent of modern health care facilities and "Western" trained personnel in urban areas of most less developed countries (40). However, these facilities are often inappropriate and inaccessible for most of the population. Such facilities are virtually non-existent in rural areas in most countries. "Western" oriented personnel do not want to work in rural areas because of such perceived lack of opportunities. In the face of such constraints, it is necessary

> "To provide rural preventive health care, "barefoot" doctor programs using paramedics, midwives, and nurses to staff clinics...." (41)

Small health centers for primarily preventive health care, and not so much of curative treatment, are required in rural areas. Some effort in this direction is being attempted in Bangladesh, though mostly by non-government organizations and foreign development agencies. Here the architect may play a vital role by assisting in the design and construction of such centers, utilizing local resources and skills, thereby reducing the cost of construction which then can be utilized for providing better health care.

There are two main arguments which support the use of indigenous materials in the construction of health centers (and also other institutional buildings. The first one, as observed in a specific example by Chrisholm, is,

> "The most successful family planning clinic was not the two storey brick/concrete building at Kathira, but the bamboo/mud clinic built as a demonstration center at Bollobpur Hospital. Here the erection of a traditional house type, enabled a better cultural identity with the village women who could see that health care did not depend on having a pucca house." (42)

Much of health care in Bangladesh is directed toward women, because of the extreme necessity for family-planning in this highly populated country. Because the society is predominantly Islamic, Bangladeshi women are in general self-conscious and uncomfortable in alien surroundings. To

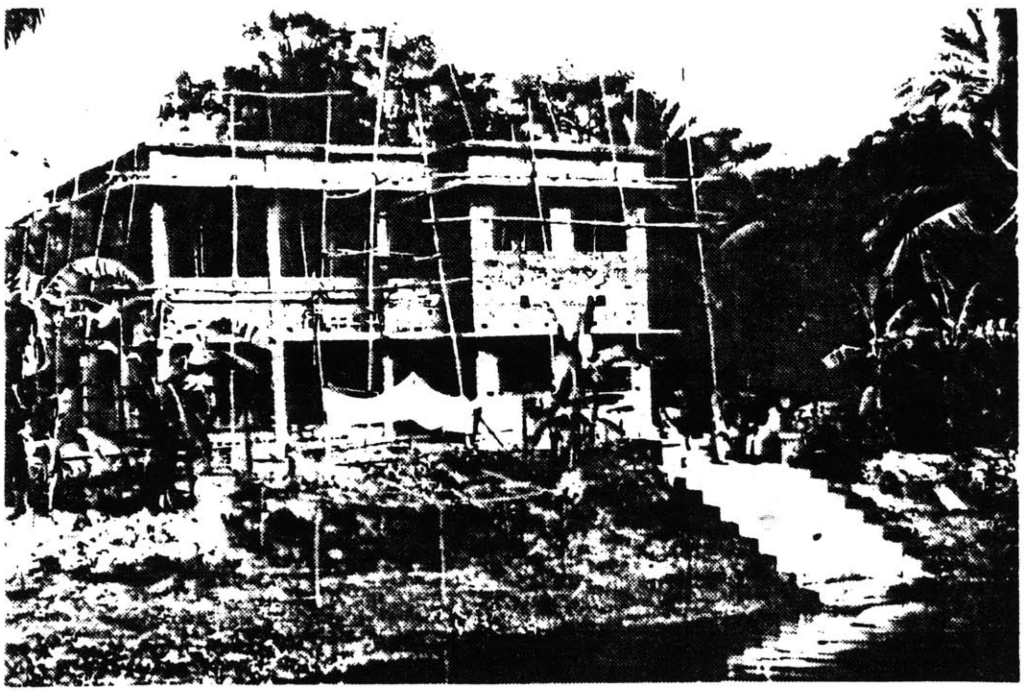


Fig. V.21. Clinic in Kathira, Bangladesh, built out of permanent, modern materials: such buildings can often be socially disruptive.

enable them to accept health care, it is arguable that the facilities should attempt to incorporate traditional elements which would be reassuring to them.

The other argument for the utilization of local materials and building patterns in institutional buildings has also been proposed by Chrisholm.

> "Two more consequences arose from the erection of the pucca clinic at Kathira. As it was the first two-storey pucca building in the locality it had become the centre of a "new village", with stores and tea shops having sprung up around it within the last year. The other consequence has been that several other centres run by CHCP have requested such a building, not so much for its appropriateness but because of the associated prestige." (43)

This incident represents the disrupting influence often created by the imposition of alien architectural symbols in traditional societies. The mere novelty of the imposition creates attraction, without consideration of the overall benefits and costs. This is the essence of the phenomenon of human choice in less developed countries, which favor the acceptance of industrialized, imported products over indigenous ones. The construction of more modern buildings in rural areas can accelerate the process of transition of traditional societies to a "Western" oriented role-model, effectively erasing most cultural values.

The case cited by Chrisholm of the women´s family planning center built out of local materials is an example of how earth and other indigenous materials have been utilized in institutional buildings. For centers larger

Fig. V.22. Women´s family planning center built of local materials: creation of a reassuring environment.

than that one, the principle of utilizing sun-dried bricks in the interior walls, as in the case of school buildings, can be employed. However, for the sake of cleanliness, the interior walls should be whitewashed with lime. Whitewash not only presents a psychologically clean appearance, but also prevents dry crust from flaking off the earthen bricks. Whitewash tends to peel off after a while, but it is an established conventional practice to renew it from time to time. Lime whitewash on inside walls is protected from being stained by dampness due to rain, and hence requires minimal maintenance.

V.3.3. Other building types:

Educational and health care buildings are the two most important social amenities which are required in rural areas. For that reason, I have dealt with them in some detail. Nevertheless, there is a host of other institutional building types which is emerging as needed in rural areas. Post offices, rural banks and administrative buildings are some of the most significant. Again, earth and other indigenous materials can be employed in various ways, in these building types. It is interesting to note that some of these types of buildings have been successfully constructed with local materials in a number of rural areas (see fig.72). Based on the locality, such attempts can be encouraged by further technical advice about stabilization techniques and preservative treatment of perishable materials, as well as about siting and orientation.

Religious buildings in rural areas have a long standing tradition of development. These buildings often serve as the nucleus of the rural community, providing cohesiveness, as well as educational facilities. During periods of disasters and strife, these religious buildings provide refuge for the affected members of the community. Having such a vital role in rural society, religious buildings would also benefit from advanced architectural advice.

The predominant religious building type in Bangladesh is the mosque. The durable and grand Sultanate mosques of the 12-14th century (44) have utilized local bricks and lime mortar extensively in many rural areas of Bangladesh. These mosques have introduced the application of corbelled brick domes covered with lime-pozzolanic plaster in rural Bangladesh, so that, in the case of mosques, domes are no longer an alien architectural form. Other simple dome building techniques with local bricks can be introduced by architects. Some of these techniques, such as the squinch and pendentive systems, can be easily mastered by local builders, which might result in the creation of larger domed volumes when necessary. This would introduce variety in the rural environment, yet would utilize local skills and resources.

The rural environment in Bangladesh also contains a

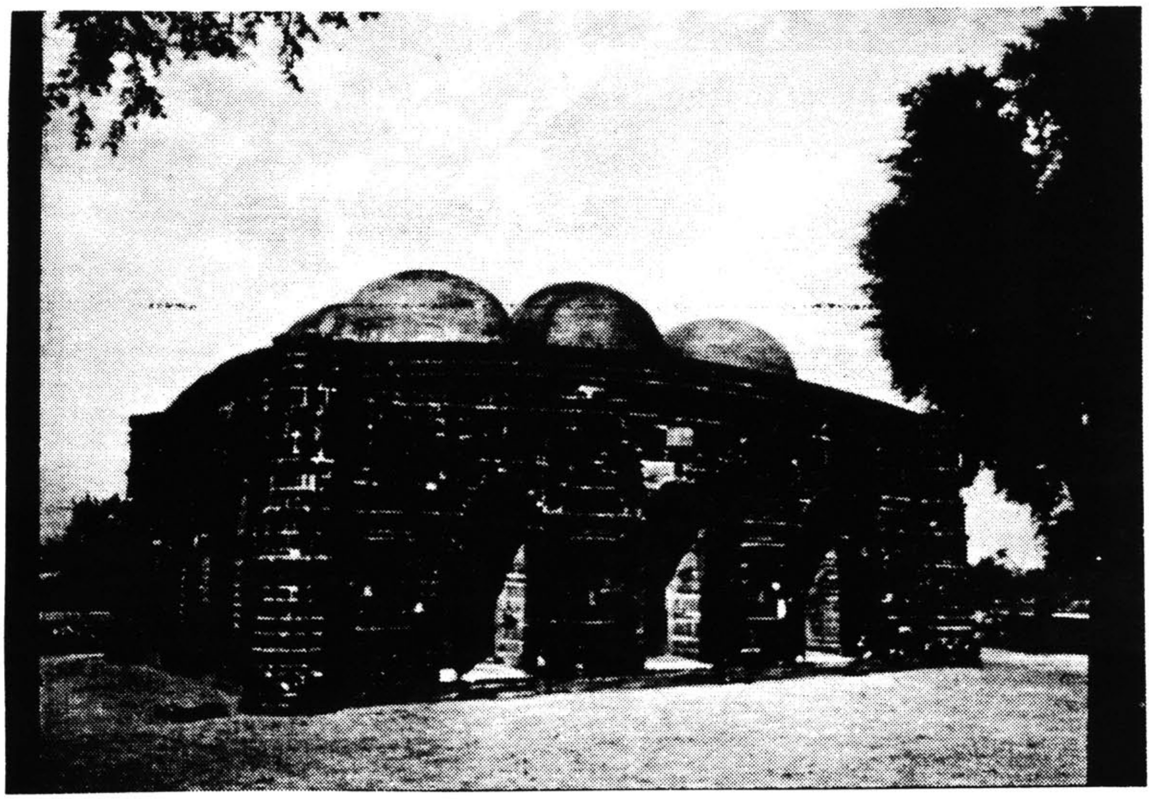


Fig. V.23. A Sultanate mosque in Bangladesh: the use of corbelled brick domes.

Fig. V.24. A village tea-house and store, built out of local materials.

Fig. V.25. Some rural shops are transitional in nature.

variety of commercial buildings - shops, tea-houses and restaurants. Most of them are built out of local materials, utilizing local initiative. Many of these buildings are transitional in nature, and are often dismantled according to the seasonal availability of business. It would be inappropriate to devise permanent and sturdy construction methods for such informal buildings. Some commercial buildings are more permanent in nature, and provision of technical assistance in such cases can be envisaged.

The role of an architect in such a context would be more as a helper than that of a designer of original buildings. Chrisholm has coined the term "para-architect" (45). Such an architect´s role would be allow indigenous ways of buildings to persist by subscribing to them, and whenever required, to provide advice for improvement in a culturally sensitive way.

V.4. SUMMARY:

Attempts to adjust to the tropical environment of the colonial tropics led to the development of "Tropical Architecture", which was essentially directed to the control of climate for comfortable habitation. The more recent developments of the Appropriate Technology movement went beyond this approach and attempted to address a variety of social, cultural and economic issues related to technological improvement in the less developed countries. The evolutionary and revolutionary aspects of this movement require reconciliation to result in culturally suitable architecture.

Earth as a building material has application in the foundations, walls and roofs of rural buildings in Bangladesh. Bamboo buildings in the coastal areas require the most improvement, and the improvisation of local wattle and daub techniques for walls may yield desirable results. However, the approach to improvement should be based on the overall benefits and costs. There is a greater potential for architectural assistance in the construction of institutional buildings. The use of sun-dried bricks and lime-pozzolanic cement in institutional buildings may prove to be a viable approach.

There is a variety of rural building types in Bangladesh, schools and health care facilities the most important, due to the demands of the present age. Religious, administrative and commercial buildings are other non-residential types. This is an area in which the architect may play an important role as technical advisor and innovator, encouraging the upgrading of local ways of building instead of imported industrialized methods.

------------------------- NOTES -----------------------------

1. Hasan Azizul Huq, "Nagini (Enchantress)," in Nirbachita Golpa (Selected Stories) (India International, Calcutta, India, 1975), trans. from Bengali and cited by Clinton B. Seely, Women, Politics and Literature in Bengal (Asian Studies Center, Michigan State University, East Lansing, Michigan, 1981), p.160.

2. The term "Third World" is gradually becoming obsolete, especially in the present-day context with the changes in Europe. To some it has pejorative connotations, e.g. "Third World" is often equivalent to being third-rate. The world is not really divided into two groups - developed and developing. Based on this particular role-model of development, the world is actually composed of countries in different stages of development. The lowest in the scale of development are the poor countries, otherwise known as the "Third World", "developing countries" (many are not developing at all!) or "underdeveloped countries", none of which is a suitable term. For the lack of an appropriate term, I have chosen to use the term "less developed countries", coined by Witold Rybczynski, as being the closest definitive description. See Witold Rybczynski, Paper Heroes (Anchor Books, New York, 1980).

3. Anthony D. King, The Bungalow (Routledge and Kegan Paul, Boston, Mass., 1984), p.46.

4. Ibid., pp.14-63. See figs.5,6 there. The caption "Appropriation of culture" had been proposed by C. Grant in 1859.

5. See Jorge E. Hardoy and David Satterthwaite, Squatter Citizen (Earthscan Publications Limited, London, 1989), pp.21-23.

6. See Hasan-Uddin Khan and Brian Taylor (ed.), "The Development Workshop," Mimar 1 (July-Sept. 1981): 37-45, for a description of the Development Workshop´s projects and goals.

7. Hassan Fathy, Architecture for the Poor (University of Chicago Press, Chicago, 1973).

8. Ernst Friedrich Schumacher, Small is beautiful (Perennial Library, New York, 1973).

9. Ronald Lewcock, "The need for special studies of the problems of Third World Architecture," Architectural Association Quarterly Vol.12 no.1 (1980): 28.

10. See U.S. Department of Housing and Urban Development, Agency for International Development, Ian Donald Terner and John F.C. Turner, Industrialized Housing, pp.IV-14 -IV-20.

11. Rybczynski, pp.83-87.

12. Khan and Taylor, p.37.

13. Ibid.

14. Rybczynski, p.50.

15. Nazrul Islam, Khadem Ali and Shahnaz Huq, "A survey of housing in a Bangladesh village," Proceedings of The Regional Workshop on Transfer of Rural Housing Technology (Dhaka, Bangladesh: n.p., 1981).

16. Rybczynski, pp.147-149.

17. M.P. Chrisholm, "Bangladesh Rural Housing Vol.II" (Bachelor of Architecture thesis, University of Newcastle upon Tyne, England, 1979), pp.134-135.

18. Ibid., p.102.

19. See Aga Khan Award for Architecture, "Grameen Bank Housing Project," Awards 1989 (Cairo, Egypt: n.p., 1989), pp.10-11. Design drawings available from Rotch Visual Collections, M.I.T.

20. The Aga Khan Award for Architecture, "Urbanization of the Satara Zone, Rosso, Mauritania," 1983 Technical review summary, section VI.

21. King, p.19.

22. Dewan Mahbub Hasan, "A study of traditional house forms in rural Bangladesh" (Master of Architecture thesis, Bangladesh University of Engineering and Technology, Bangladesh 1985), pp.183-184.

23. R.J.S. Spence and D.J. Cook, Building Materials in Developing Countries (John Wiley & Sons Ltd., New York, 1983), pp.315-318.

24. L.J. Goodman, et. al., Low-cost housing technology (Pergamon Press Ltd., New York, 1979), p.209.

25. Hasan, p.184.

26. John Norton, Building with earth (Intermediate Technology Publications, Rugby, U.K., 1986), p.55. Also

see, Mario Mendonca de Oliveira, "The study of accelerated carbonation of lime-stabilized soils," Getty Institute for Conservation, Proceedings of the 6th International Conference on the Conservation of Earthen Architecture (Adobe 90 Preprints) (Las Cruces, New Mexico: n.p., 1990), pp.166-170.

27. Norton, p.55. Also see, Spence and Cook, p.54.

28. Chrisholm, pp.82-83.

29. Ibid., p.114.

30. Rybczynski, fig.33.

31. Spence and Cook, p.277.

32. Hasan, p.62.

33. Spence and Cook, p.277.

34. Chrisholm, p.74.

35. See The Fontana Dictionary of Modern Thought, 1988 ed., on "Education", p.254. Also, The New Columbia Encyclopedia 4th ed., p.834.

36. Ivan Illich, Deschooling society (Harper and Row, New York, 1946).

37. Bangladesh Ministry of Information, External Publicity Wing, Bangladesh Diary 1990. See section on "People".

38. Michael P. Todaro, City Bias and Rural Neglect: The Dilemma of Urban Development (The Population Council, Inc., New York, 1981), p.62. Todaro has written on integrated rural development in a number of books, but I will mainly refer to this publication because of its broad manner of dealing with the subject.

39. Ibid., p.62-63.

40. Ibid., p.62.

41. Ibid., p.62-63.

42. Chrisholm, p.71n.

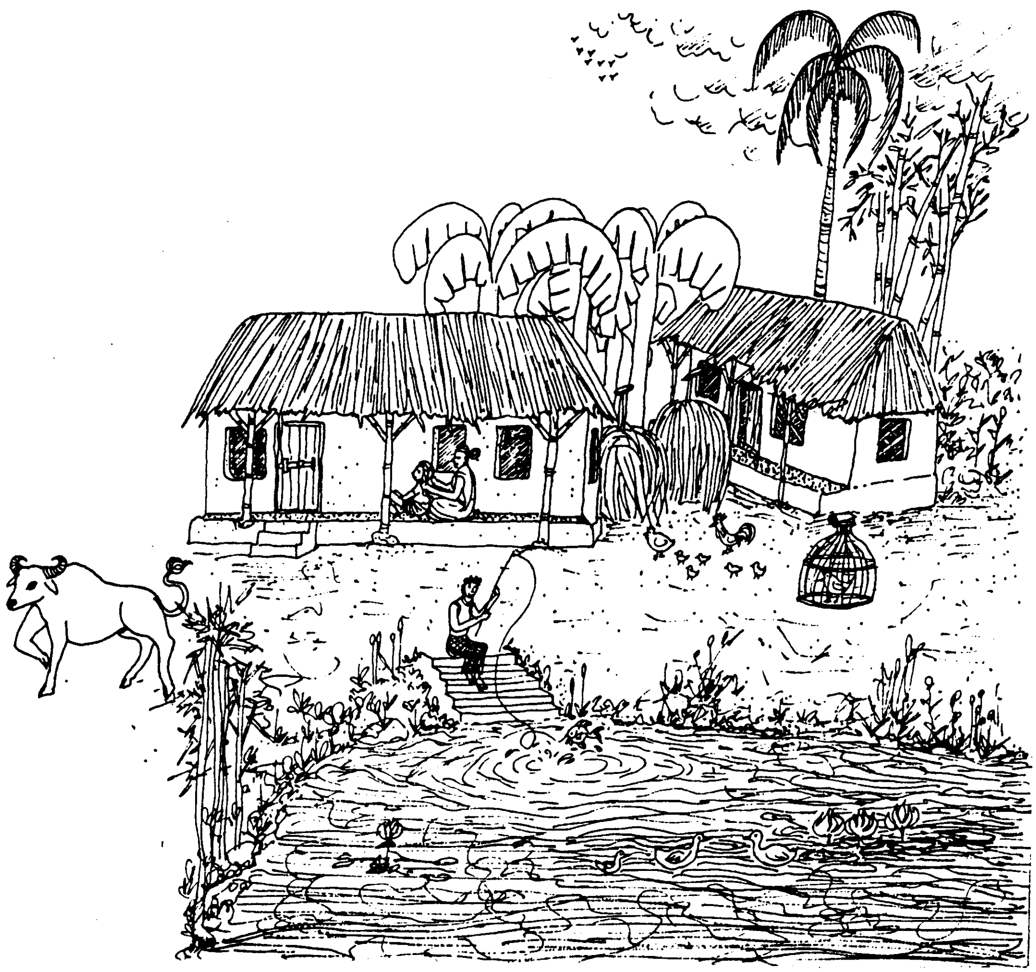
43. Ibid., Vol.I, p.70n.

44. See Nazimuddin Ahmed, Discover the monuments of Bangladesh (University Press Limited, Dhaka, Bangladesh,

1984).

45. Chrisholm, p.124.

CHAPTER VI



"She pictured their new house. She saw three clean rooms on the north, east and west surrounding a central courtyard. In one room would live the husband and wife; in another their son would live with his wife; and the third room would remain vacant for their daughter and her husband. Bhanumati is a good Bengali housewife. She knows how to arrange a family. She has a rich fund of experience. Does she not know how to bring happiness to the family? In her mind's eye she conjured up pictures of a cowshed, a milking cow, a plow and bullocks, arable land, a pond full of fish, and a full granary." (1)

CHAPTER VI: CONCLUSION

The previous chapters dealt with a variety of themes as related to indigenous and earthen architecture of Bangladesh. Many theories, techniques and strategies for improvement had been discussed. It is necessary, at this point, to extract and clarify my approach towards the improvement of indigenous architecture in Bangladesh.

There have been essentially two broad thematic aspects to this thesis. The first one has been to identify strategies for improvement based on non-technical reasoning. Various social, cultural and economic factors have been taken into account, in order to critically assess the appropriateness of innovative techniques and theories. The second aspect is more technical in nature. I have considered the possibilities of innovative improvement strategies for different parts of buildings, as well as for different types of buildings.

Regarding the first aspect, most innovations have been found to be unsuitable in Bangladesh, because of their high costs and sophisticated modes of operation. In such circumstances, the second aspect was concerned with to seek for improvement strategies which would be affordable and simple. This evidently means that the proposed strategies would be very modest in scope. Therefore, this thesis is basically a re-appraisal of the indigenous and earthen architecture of Bangladesh, with the intent of finding ways to allow the traditional building methods to continue with minimal change.

Much of the indigenous architecture is highly refined and does not really need change. Only for two specific reasons is there a need to develop improvement strategies. The first one is that, in spite of being so highly refined, some weaknesses are evident, especially in the context of present-day environmental and social change. The other reason is that some modern materials, especially C.I. sheets, have become widespread and acceptable; improvement strategies to adapt such materials to the context of Bangladesh have been felt to be necessary.

One material has surfaced repeatedly in the different discussions in this thesis, which is lime. This readily available and inexpensive material has immense potential to be combined with earth or earthen products. Its use has been discussed in a variety of ways. Stabilization of soil with lime is one of its uses, for wattle and daub walls, large earth blocks and sun-dried bricks. Its other use is to be combined with "surkhi" to form lime-pozzolanic cement for foundation slabs, floor finishes, column bases, mortar and plaster.

An important aspect of rural development has been attempted to be addressed in this thesis, which is the construction of institutional buildings. I believe that this is the area where architects can make useful contributions, by applying research in indigenous building materials and techniques to these institutional buildings, which may become models for residential buildings. This is the area which might re-define the future architecture of Bangladesh.

The issue of human choice has been left largely unaddressed. I have aspired to write a document which would have practical applications and would be useful. However, to make such a document useful, it has to relate to human choice. Therefore, social surveys to assess its viability as related to human choice have to be conducted at some point, before it can be put to any practical application. It is with this hope that it will make a fruitful contribution to architecture and society in rural Bangladesh that this whole thesis has been written.

------------------------- NOTES ----------------------------

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GLOSSARY

Absorptivity Used of materials, the constant a in Beer's law relation A = abc, where A is absorbance, b the path length and c the concentration of the solution (or density of the material). Also known as absorptive power.

Alluvial Pertaining to alluvium; the detrital materials eroded, transported and deposited by streams.

Asphalt A brown to black, hard, brittle, or plastic bituminous material composed principally of hydrocarbons. Prepared by pyrolysis from coal tar, certain petroleums, and lignite tar; it melts on heating, is insoluble in water but soluble in gasoline; it is used for paving and roofing, for the stabilization of sun-dried bricks, and also in paints and varnishes.

Bitumen The main constituent of asphalt; this term is more prevalent outside the U.S., especially in the U.K.

Capillary rise, Capillarity The action by which the surface of a liquid where it contacts a solid is elevated or depressed, because of the relative attraction of the molecules of the liquid for each other and for those of the solid. By this action, subsoil or ground water rises up through certain porous building materials into the foundations, walls and floors of buildings.

Corrugated To form straight, parallel, alternate ridges and grooves in sheet metal, cardboard or other material.

Cross-bracing In the case of this thesis, bamboo poles which are fastened diagonally across posts or other bamboo poles, so as to impart rigidity to a framework.

Diurnal Pertaining to meteorological actions which are completed within 24 hours and which recur every 24 hours. Diurnal temperature variation refers to the daily changes in temperatures from day to night.

Dry compressive strength Property of a material when it is in a dry state to resist rupture under compression.

Emissivity The ratio of the radiation emitted by a surface to the radiation by a perfect blackbody radiator at the same temperature.

Galvanize To deposit zinc on the surface of metal by the process of hot dipping, sherardizing (tumbling in powdered zinc at about 250-375 degrees Centigrade) or sometimes electroplating.

Glazes Thin continuous glassy coatings, usually prepared from fused silicate mixtures fusion-bonded to ceramic structures; commonly applied on claywares or other ceramics for protective, marking, sealing, or decorative purposes.

Hydrated lime Calcium hydroxide; quicklime combined (slaked) with just enough water to satisfy its chemical affinity for water. It has the advantage of being dry and yet, when mixed with other ingredients, is ready for use in plastering in a much shorter time than unslaked lime (quicklime). In order to develop the necessary plasticity in normal finishing hydrated lime, it must be made into putty and soaked from 12 to 15 hours before using. The finishing hydrated limes contain about 60% of calcium and 40% of magnesium.

Jute sticks Branches from the jute plant; hollow, brittle and perishable stems.

Lime Also called quicklime, is calcium oxide, a white or grayish white, finely crystalline substance that sometimes has a yellow or brown tint because of iron impurities. Obtained by burning, from limestone or dolomite, and also by leaching sand and from broken shells and coral.

Lime mortar Mixture of hydrated lime, sand and water, with proportions of lime:sand = 1:2 or 1:3. While using a burnt clay pozzolan the proportions may vary from 1:2:8 = lime: pozzolan: sand if a finely-ground pozzolan is used, to a 1:1.5 = lime: pozzolan mixture with a coarse brick dust pozzolan (surkhi).

Mud slurry A free flowing suspension of unindurated mixture of clay and silt in water.

Physiography, Physiographic form A landform considered with regard to its origin, cause or history.

Pleistocene An epoch of geologic time of the Quaternary period, following the Tertiary and before Holocene. Also known as Ice Age.

Polymer Substances of giant molecules formed by the union of simple molecules (monomers).

Polyethylene Also known as polythene in the U.K.; a polymerized ethylene resin, used especially in the form of films and sheets for packaging, or molded for a wide variety of containers, kitchenware and tubing.

Pozzolanic reaction, Pozzolan A finely ground burnt clay or shale resembling volcanic dust, found near Pozzuoli, Italy; used in cement because it hardens underwater. Cement made by mixing and grinding slaked lime and pozzolan without burning, in the ratio lime:pozzolan = 5:1. In the case of Bangladesh, the pozzolan used is powder from fired clay products.

Pucca Bengali word for solid and permanent, as opposed to Kutcha, which means perishable and impermanent.

Reflectivity The ratio of the energy carried by a wave which is reflected from a surface to the energy carried by a wave which is incident on the surface.

Rice husk Outer coat of rice seeds, particularly a dry membranous structure. Fulfills the same function of a binder in earthen construction as straw does.

Seminole A tribe of Muskhogean-speaking Native North Americans, a late Creek offshoot, originally living in Alabama, later in Florida, but now chiefly in Oklahoma.

Shortwave radiation A term used loosely to distinguish radiation in the visible and near visible portions of the electromagnetic spectrum (roughly 0.4 to 1.0 micrometer in wavelength) from longwave radiation (infrared radiation).

Slaked lime Dry quicklime is broken up and saturated with water to form calcium hydroxide; this is a vigorous reaction and must be controlled because of the large amounts of heat generated.

Sump oil Oil, generally petroleum oil, from a pit or tank which receives and stores drainage at the lowest point of a circulating or drainage tank. Mostly an industrial by-product.

Surkhi Bengali name for powder from fired clay products like bricks, tiles, pottery etc. Produced by breaking waste or broken clay products, and passing through a sieve to obtain a coarse dust. Used as pozzolan with lime for roof terracing.

Termite A soft bodied insect of the order Isotera; individuals feed on cellulose and live in colonies with a caste system comprising three types of functional individuals: sterile workers and soldiers, and the reproductives. Also known as white ants. Well known for attacking moist wood, or old wood with fungus growth, from which they derives nourishment.

Tertiary Hills Land formed during an epoch of geologic time of the Quaternary period, prior to the Ice age or Pleistocene period.

Vitrification The act or process of changing or making into a glassy or non-crystalline material; glazes applied on ceramic pieces or structures vitrify due to firing.

Whitewash A simple mixture of hydrated lime and water, used mostly for painting interior walls, but also for exterior walls in some cases.

---------- ILLUSTRATIONS AND PHOTOGRAPHIC CREDITS ----------

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