2. Building Technologies for Hazard Resistant Housing

2.1 Introduction

A great part of the material in this book has resulted from studies and work carried out under a higher educational link between two engineering schools, one at BUET (Bangladesh University of Engineereing and Technlogy) and the other at the University of Exeter, UK. Because of this, the emphasis has been on developing and promoting building technologies for hazard-resistant housing. Nonetheless, the underlying concern has been that the technologies should be appropriate, affordable and achievable in rural circumstances, a reason for subsequently conducting field-level grassroots studies to test in reality the applicability of the results of the laboratory studies. A large amount of technical studies have been carried out, so it was essential that some of the main findings find their way into this chapter.

This chapter begins with a description of mud stabilisation and bamboo structure tests at BUET. The results of the mud stabilisation tests were also utilised in the field. The effect of strong wind on housing is an important factor in building hazard-resistant housing and reducing vulnerability, and a large part of this chapter is devoted to the topic. Firstly, two main aspects are covered: a) experiences of multipurpose cyclone shelters and b) technologies for improvement of wind-resistance of traditional housing. Secondly, results of wind tunnel tests on the behaviour of model rural houses under different wind conditions conducted mainly at the University of Exeter are presented. These provide useful guidelines for stronger construction details, planting vegetation and other such hazard-resistance measures to safeguard rural houses against strong wind. An inventory of post-disaster housing types provided by organisations in Bangladesh, some of which incorporate hazard-resistant technologies, is then included to indicate the state of the practice beyond the confines of the BUET-Exeter studies. The final section attempts to gel together the lessons offered by the technical studies by relating them to economic, social, environmental and other multidimensional aspects.

2.2 Hazard Resistant Rural Houses

Natural disasters, particularly extreme winds and floods, have been causing huge loss of lives and properties every year in Bangladesh. Most of the Bangladeshi population lives in rural areas where the construction of residential houses follows a traditional way in which houses are mainly constructed with thatches, bamboo, etc., with untreated earth base having minimum or no foundation. In most cases, these structures have almost no lateral load resistance mechanism. During floods, rural houses go under water causing severe damage to their bases. During wind events, the frames of rural houses undergo partial or total collapse as they have little or no lateral load resistance. Here some treatments and techniques are proposed for the improvement of rural house bases, and the vulnerability of rural houses to failure due to cyclic moderate wind loading is shown.

2.2.1 Development of Durable Plinth

During floods, many house bases go under water for a certain period. After the recession of flood-water, it is usually found that most of the bases are either washed away or have been damaged to a considerable extent. Development of water-resistant mud-concrete is essential to making house bases more durable.

The bases of the rural vernacular houses are made from soil in the traditional way. Loose soil is heaped at the location where the base is to be prepared. Water is added to make mud and it is positioned in the periphery of the base area like a boundary wall of height about 60-120 cm. Within this boundary the rest of the soil is dumped and mixed with water to prepare mud. Then the mud is heaped and compacted up to the desired height of the plinth.

Since the plinth is a very important part of the house, it should withstand the effects of flood. The first part of the investigation included determination of the properties of soil mixed in the laboratory with some additive or cementitious materials. This mixture has been termed here as mud-concrete.

In this study, rice husk (RH), rise husk ash (RHA) and cement (C) were used to make the mud-concrete.

The cementing materials were mixed with the soil in different proportions then water was added to prepare the mud. The net weight of the soil and the cementing material in each of the cases was fixed at 68 kg. The percentage of the ingredients RH, RHA or C was fixed at 5% by weight. To make the mixture to a desired consistency, water (4000 cc) was added to make the mud-concrete. The sample was then put in the wooden mould of size 81 cm x 35 cm x 15 cm (Figure 2.1) to make a continuous soil bed of size 75 cm x 30 cm x 15 cm in five layers (Serajuddin, M., 1980). In each layer, 25 nos. of blows were given with a 11.3 kg hammer from 15 cm height. After four days it was cut into ten pieces to have cubes of size 15 cm x 15 cm x 15 cm each. The compressive strengths of the samples with different combinations are given in Table 2.1. Mud Cement blocks of various sizes were also prepared in cube moulds (Figure 2.2). These were dried and tested under water for more than two months (Figure 2.3) and the blocks remained in intact condition.

Table 2.1: Compressive Strength of the Mud-Concrete

Combination	Cross-Sectional area (cm^2)	Height (cm)	Max Load (kg)	Compressive strength (N/mm^2)
Soil	224.5	15.2	3810	1.70
Soil + HRA	217	15.2	3991	1.81
Soil + C	220	15.2	3129	1.41

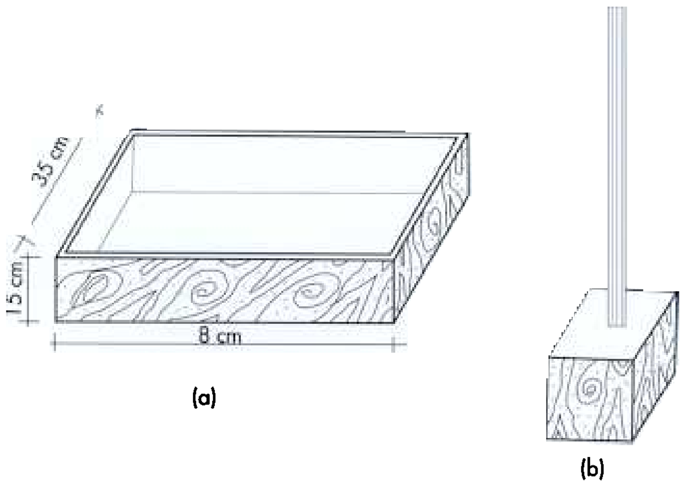


Figure 2.1: Preparation of Mud-Concrete, (a) Mould, (b)Hammer

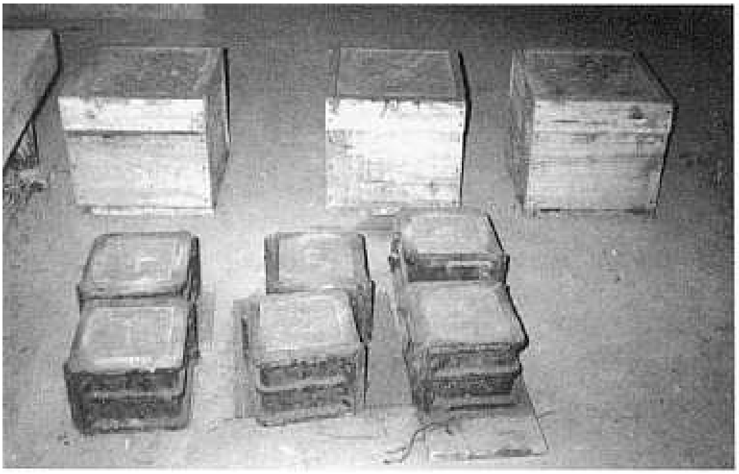


Figure 2.2: Mud Cement Block Preparation

The dry samples of different combinations (soil, soil+RH, soil+RHA, soil+C) were placed on a tray and kept under water for ten days to get an idea about the effect of flood on the bases of rural houses. When the tray along with the samples was taken out of water after ten days, it was observed that all other samples except the cement-mixed soil washed away. It appears that although the compressive strength of cement mixed soil (soil+C) is not the best of all the mud-concretes, it produces a better plinth to withstand the effects of flood. The effect of the percentage of cement and also the use of jute-fibre, straw, etc. as cementing materials in the mud-concrete is yet to be investigated.

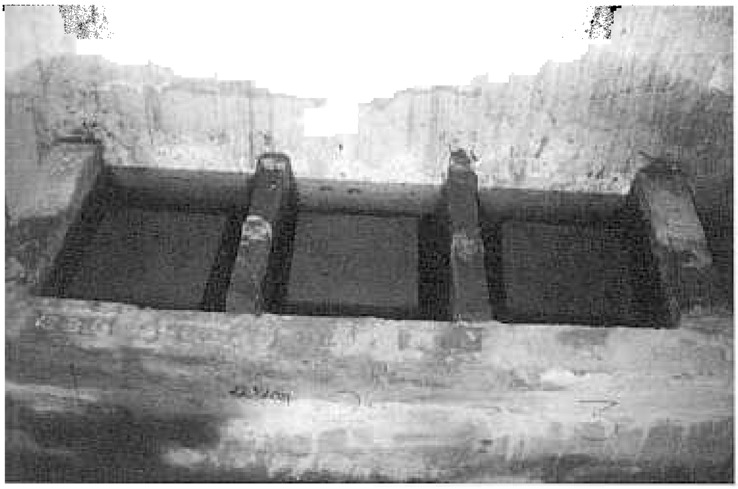


Figure 2.3: Mud Cement Block Under Water

2.2.2 Common Failure Modes and their Prevention

The authors made visits to several villages with a view to studying the framing as well as base preparation techniques and it was found that the techniques are more or less similar. Bamboo columns are traditionally being used as the main supporting members. The columns are embedded directly into the ground, which tend to decay in contact with sub-soil water. In most places, sub-soil insect attack on bamboo columns forces the house owners to replace the columns frequently. Poor households are unable to afford and replace bamboo in necessity, which leaves their houses weak and vulnerable to moderate wind. Reinforced cement concrete pillars can be considered as a great innovation for this problem; but the poor rural people often cannot afford them.

Instead of replacing bamboo columns with reinforced cement concrete pillars, their performance with respect to sub-soil water or insect attack at their base can be improved by using concrete blocks with a hole at the center for insertion of the bamboo column. Before insertion, the end of the post can be coated with a layer of bitumen for further protection from water or insects. A less expensive and simpler method would be to burn the lower part of a bamboo column until its surface color becomes black and then to coat it with motor oil as shown in Figure 2.4. Scorching dries the bamboo out completely and depletes internal cellulose from which insects derive nourishment, thus retarding insect attack. When scorching bamboo, caution needs to be exerted that it does not burn all the way through (Figure 2.5). Coating it with oil prevents further access by insects and additionally protects from sub-soil water. Instead of motor oil, bitumen can be used where available. Motor oil, an industrial by-product, is generally less expensive than bitumen, but bitumen performs better. A summary of bamboo treatment is shown in Figure 2.6.

The lifting of the leeward roof slope of rural houses is another very common problem in Bangladesh. The total wind force on the roof depends on the difference of pressure between the outer and inner faces. Any open doors, windows or ventilators on the windward side of a house can increase air pressure inside the building and this also increases the loading on those points of the roof and walls that are subjected to the external suction. Openings at positions that are experiencing external suction will also reduce the pressure significantly inside the house and thus reduces the risk of lifting the roof off the house. Use of jute ropes or special

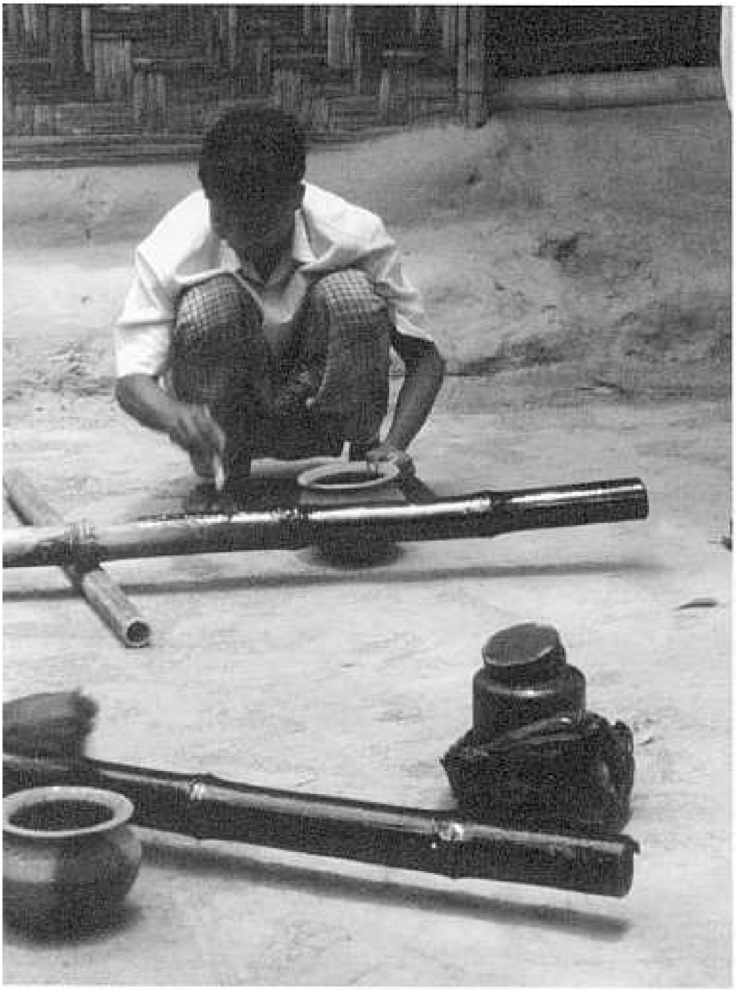


Figure 2.4: Coating Bamboo with Bitumen

Figure 2.5: Scorching Bamboo

type of rope, locally called *sutli,* to fasten the joint where horizontal and vertical members meet, aggravates the problem as the jute ropes rot and become weak within a very short period of time and thus the vulnerability of roof to lifting increases. With a view to strengthening the joint, several cores of iron wire can be twisted together and the roof frame can be tied down to the top wall beam and column as shown in Figure 2.7 and Figure 2 .8

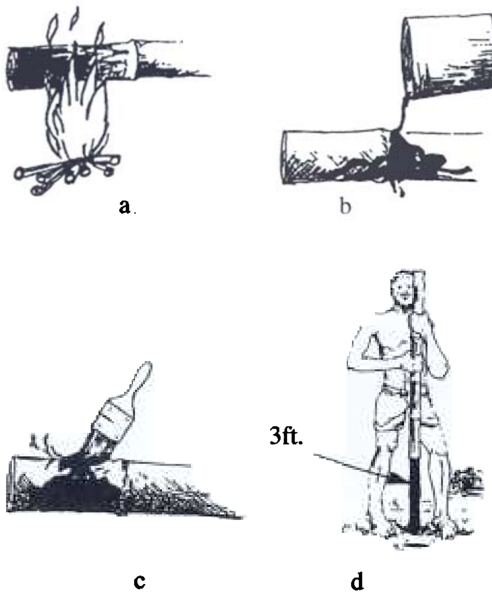


Figure 2.6: Treatment of Bamboo Column, (a) Scorching the Bamboo, (b) Covering with Motor Oil, (c) Soaking in Bitumen, (d) Placing the

2.2.3 Properties of Bamboo as a Framing Material

Generally three types of bamboo are available in Bangladesh. They are locally called *mahal* or *talla, ora* and *barak.* Among them barak is relatively thick-walled and widely used as column and beam which are locally named *khuti* and *paire/dhynna* (the beam along the long side or the beam along the short side), respectively. Other types of bamboo are usually thin-walled and are split and woven into a variety of stiff mats that are used as walls and sometimes as roof cladding.

To determine the strength characteristics of bamboo, compression tests have been performed on bamboo specimens of length 20-25 cm and full sized bamboo of length 150-152 cm (Figure 2.9a). For tensile strength, the bamboo was split and a reduced section was prepared as shown in Figure. 2.9b. Compression test results of both types of bamboo specimen and the tensile strength characteristics of bamboo are given in Tables 2.2, 2.3 and 2.4 respectively.

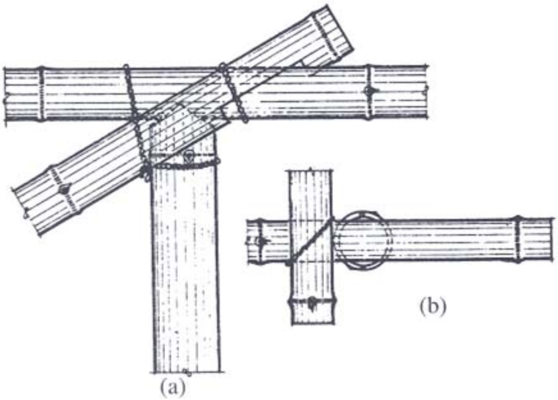


Figure 2.7: Connection of House Frames,
(a) Three-Dimensional View
(b) Top Plan of a Joint

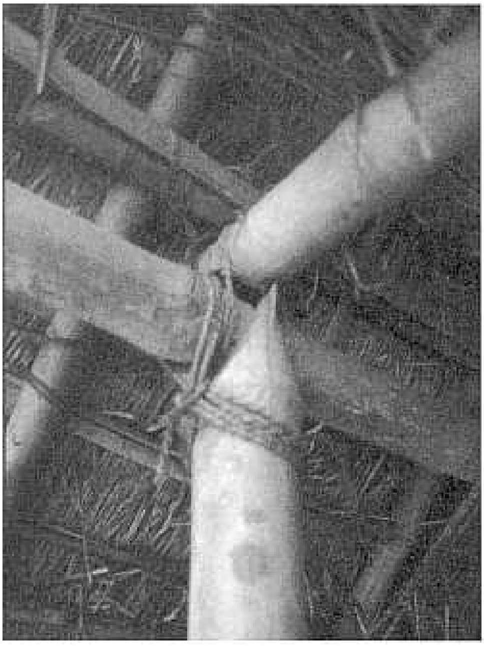


Figure 2.8: View of a Frame Connection

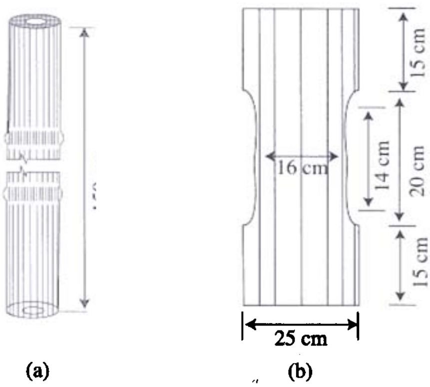


Figure 2.9: Specimens prepared for Testing,
(a) Full-Sized Compression Test Specimen,
(b) Tensile Test Specimen

Buckling failure was observed for the full-sized specimen (Figure. 2.10) and the buckling strength was found to be 0.56 times the compressive strength of the shorter bamboo specimen. On the other hand, it is seen that bamboo is very strong in tension and the tensile strength is about 4.4 times of the compressive strength of a full-sized bamboo specimen. Unless it becomes weak due to insect attack or by rotting, bamboo was found to be safe to withstand the stresses caused by moderate wind-induced lateral load.

Table 2.2: Compression Test Results of Bamboo (Barak) Specimen

Specimen No.	Length (cm)	Outer dia. (mm)	Thickness (mm)	Ultimate load (kg)	Compress strength (N/mm²)	Average strength (N/mm²)
1	21	58	15	8934	43.3	
2	21	58	15	9524	46.1	
3	21	60	16	10431	46.3	45.1
4	19	69	16	12472	45.9	
5	23	74	18	12698	39.3	
6	22	65	16	12472	49.7	

Table 2.3: Compression Test Results of Full Size Bamboo (Barak)

Specimen No.	Length (cm)	Outer dia. (mm)	Thickness (mm)	Ultimate load (kg)	Compress strength (N/mm²)	Average strength (N/mm²)
1	152	59	11.5	4535	25.9	
2	152	63	13.5	4580	21.4	25.4
3	150	58	11	4807	29.0	

Table 2.4: Tensile Test Results of Bamboo (Barak) Specimen

Specimen Number	Section (mm)	Ultimate load (kg) (N/mm²)	Tensile strength (N/mm²)	Average strength
1	15 × 13	1814	91.3	
2	18 × 10	2403	131.0	112.5
3	17 × 10	2041	117.8	
4	16.5 × 10.8	1995	109.8	

2.2.4 Full Frame under Cyclic Lateral Load

In order to understand the wind resistance potential of a rural hut under cyclic moderate wind loads, a full-scale model hut was tested under two cycles static load. Although the science of theoretical fluid mechanics is well developed and computational methods are experiencing rapid growth, it remains necessary to perform physical experiments to gain insights into many fluid flow effects. It is necessary for the houses subjected to wind loads to be sufficiently strong to perform adequately from a structural safety and serviceability viewpoint. From dimensional analysis, it has been shown (Simiu et al. 1986) that the similarity requirements between the model and the prototype are exactly satisfied when and only when the two systems have exactly the same scaling. From this standpoint, full-scale model produces the best possible result. On the other hand, the natural wind is turbulent, and the phenomena that takes place in the boundary layer of wind is highly dependent on the nature of this boundary layer. Due to the physical limitations in simulating the natural wind in the experiment, static load was applied instead.

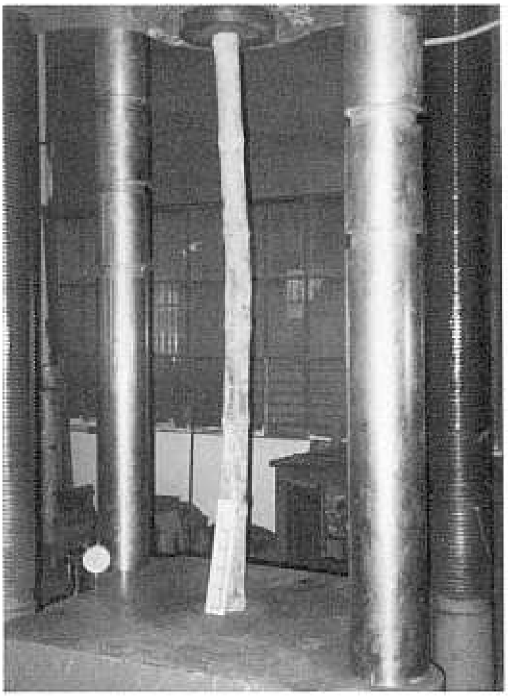


Figure 2.10:Testing of Full-Sized Bamboo Specimen

An experimental set-up is shown in Figure 2.11. Static load was applied uniformly to the frame of the house through a loading jack, plan view of which is shown in Figure 2.12. The deflections of the house frame caused by static lateral loads were measured by a theodolite. During application of the first cycle of loads, some small cracks were observed on the base soil adjacent to the bamboo columns and no repairs were made before the second cycle of loading. This has been done to simulate the phenomena of frequent storms of moderate speed that do not actually cause total collapse of the house. It is observed from Figure 2.13 that deflections during the second phase of loading are larger than that of the first cycle. This observation can easily be extended to the fact that the house will collapse under cyclic moderate wind loading if remedial measures are not taken in between. The remedial measures might be to strengthen the loose soil adjacent to the column base by hammering and/or to provide lateral support to the main frame of the house on the leeward side of the house.

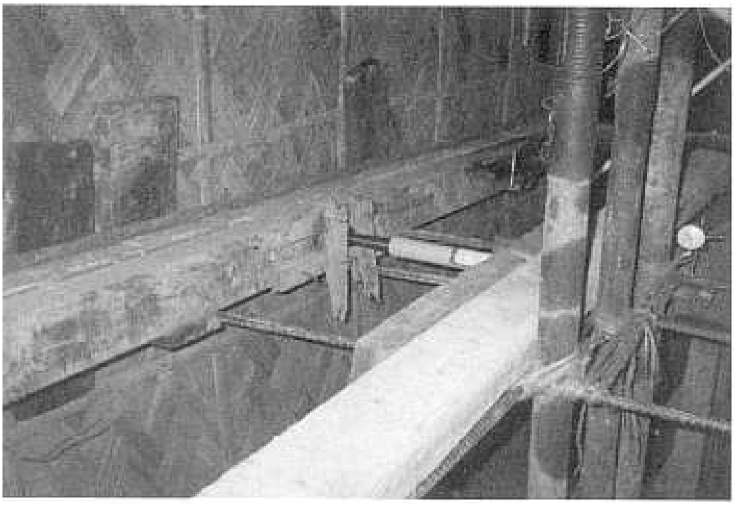


Figure 2.11: Test Set-Up of Full-Scale Rural House Under Lateral Load

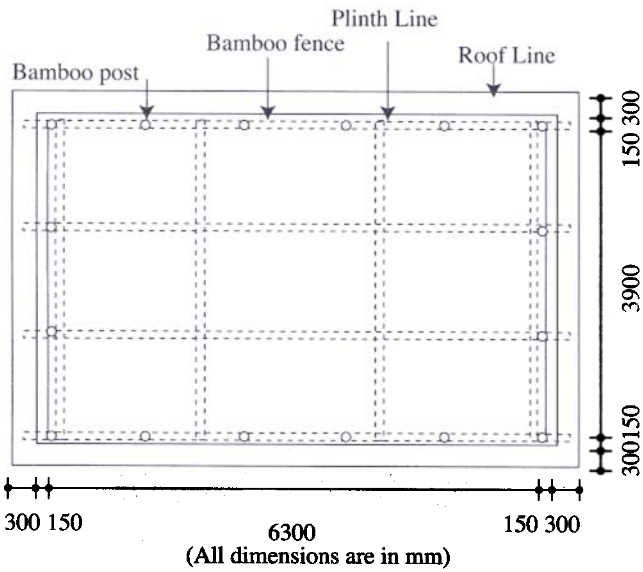


Figure 2.12: Plan View of House Under Test

Traditional rural housing is very light and fragile, and has the simplest form consisting of a skeleton of bamboo framing formed by four corner poles framed by four struts in the horizontal plane at a height of 1.5-2.0 meters from the plinth level. Anwar (1996) has analysed such a basic frame as shown in Figure 2.14 with different kinds of wind braces and has shown that the lateral and torsional stiffness of the basic frame can be increased by more than 100 times by using vertical cross-bracing along the four sides of the house. The effect of lateral bracing on the lateral load resistance of the full-scale model is still under investigation.

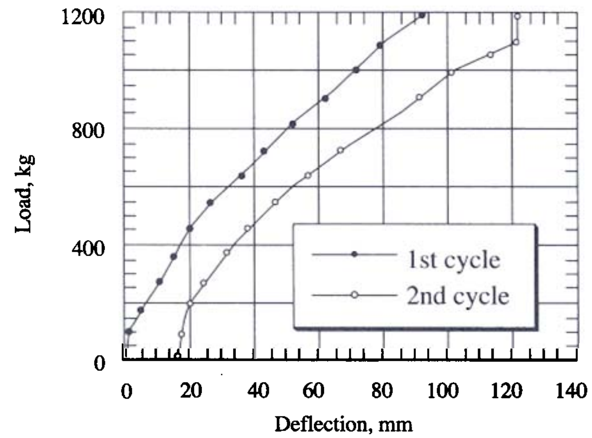


Figure 2.13: Behaviour of House Frame under Cyclic Loading

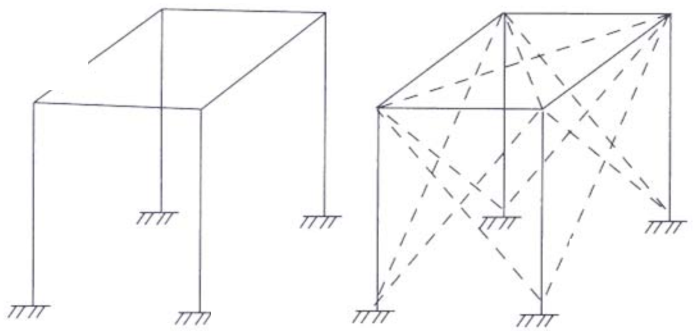


Figure 2.14: Effect of Wind Braces, (a) Basic Frame, (b) Basic Frame with Lateral Braces.

2.2.5 Future Directions

An experimental investigation has been carried out to understand the effects of flood on the plinth soil and to clarify the vulnerability of rural houses to cyclic wind loading. Based on the experimental results, the use of cement-soil mixture with 5-8 % cement by weight has been suggested to prepare the plinth of houses of flood-prone areas. Remedial measures have been advised which will create a strong safeguard against the repeatedly occurring moderate storms.

Future investigation is to be continued with changing the percentage of cement in the mud-concrete, instead using 5-8 % by weight. In field conditions mixing may also be done by volume; understandingly, the percentages may not be that accurate, but it would allow convenience of application. Effect of different kinds of lateral bracing on the lateral load resistance potential of the full-scale house frame is still under investigation.

2.3 Cyclone-Resistant Domestic Construction

The Multipurpose Cyclone Shelter Project (MPCSP), financed by UNDP and the World Bank and undertaken in 1992/3 (BUET/BIDS, 1993), was a detailed study with the objective to provide cyclone shelters for refuge for the population of cyclone-prone areas of Bangladesh. Subsequently, an interim Study Project has been undertaken to assess the feasibility of a construction programme and to ultimately prepare contract documentation. This subsequent study has adopted the sub-title of the "Cyclone-Risk Area Development Project".

In its consideration of domestic dwellings, the MPCSP Report "Master Plan" (BUET/BIDS, 1993) made reference to houses of *pucca* (durable) construction in recognising that private residences play a significant role as safe havens (shelters) in cyclones and that strongly built *pucca* private residences with two or more stories saved many lives in the April 1991 cyclone.

The Master Plan includes discussion of settlement patterns and of a survey for the preparation of an inventory of one-storied private buildings for conversion to provide more secure refuge in cyclones. It does not include reference to the quality, poor or otherwise, of which the majority of rural dwellings are constructed.

More than eighty percent of the population of Bangladesh is classified as rural, according to the 1991 Census. Although the number of pucca constructions increased by several hundred percent during the ten years, 1981-91, the national average proportion of pucca buildings to total household numbers is still only 2.18% (BBS, undated). Thus, more than nine million houses, occupied by over 90% of households, are of less than pucca construction. The need for improved kutcha construction for dwellings, therefore, relates to their far greater number and to a prevailing context of poverty.

The ADB Report of the Housing Sector Institutional Strengthening Project (Halcrow Fox, 1993) reviews the involvement of NGO and aid programmes in these contexts. It includes an assessment of the performance, strategies and institutions of the urban and rural housing sector, particularly the provision of shelter and services to low-income households, noting that:

- 82% of dwellings in Bangladesh are in rural areas.
- 75% of rural dwellings are of kutcha construction (non-masonry, bamboo, reeds, jutesticks, etc.).

- 23% of urban and more than 40% of rural dwellings are of temporary construction (lesser quality than *kutcha*).

These data reflect the prevailing poverty of rural populations in a context of floods and tropical cyclones. Also, most low-income households lack fresh water, sanitation, cooking facilities and energy supply. However, in contrast to urban residents, up to 95% of rural people, including those classed as "landless", may own at least the land on which their dwelling is located.

Rural housing need is assessed on the basis of kutcha dwellings being regarded as substandard and requiring replacement with pucca construction. In that case, annual construction of 2,167,000 dwellings would be needed, including replacement of all "substandard" dwellings over a seven year period (Halcrow Fox, 1993). The Government of Bangladesh has accepted that it does not have the resources for such an enormous undertaking and is therefore adopting an enabling approach for the provision of improved housing within a national housing policy.

This suggests that in cyclone-prone areas there is a socially perceived need for improved construction of dwellings and that assistance to build stronger homes would be appropriate. "Community houses" might also be built in pucca construction to serve say 50 households in places where other forms of cyclone shelter are remote. Such community houses could be used normally as residential accommodation for a teacher; the land would be donated and the building maintained by the community.

Field sources have also commented that the dangers of flying roof sheets discourage people from leaving dwellings to go to shelters. In 1991 three people were killed in this way at Bakerganj; as the embankment was not overtopped at this place, they would probably have survived the cyclone otherwise. Improved construction would reduce this risk and at the same time make it less dangerous to stay at home.

Improvements in housing standards must be undertaken in conjunction with development of sea and river embankments and increased understanding of the impacts of storm surge flooding.

2.3.1 Improved Domestic Construction for Cyclone Resistance

Pucca materials (brick, block work and corrugated galvanised iron (cgi) sheet) have been in use for so long that it is often difficult to make a useful technical distinction between "traditional" and "non-traditional" construction. Kutcha and pucca combine in the form of semi-pucca buildings and cgi sheets are used in all forms of buildings and for many purposes (walls, roof, water channels, fencing, etc.).

Traditional construction takes forms reflecting cultural expressions as well as expediency. It is used by the majority of rural dwellers, both landowning and landless. While there is room for improved cyclone resistance in pucca construction, the need for it is much greater among the millions of people dependent upon traditional materials and construction methods.

Previous initiatives to improve domestic construction in Bangladesh have mostly focused on the use of non-traditional materials such as reinforced concrete or steel framing. This implies an inadequacy of traditional materials, whereas the real need is, instead, to improve traditional construction methods.

Cyclone-resistant traditional building technologies have been largely neglected for the following reasons:

- The major cause of damage and death in cyclones has been the accompanying storm surge; non-pucca construction has been swept away regardless of its quality.
- Embankments have largely failed to protect homes, either because they did not exist or were insufficiently maintained.
- There is a tendency to spend as little as possible on domestic construction since the investment is likely to be washed away in the next storm surge.

2.3.2 Hazard Class

Five hazard classes have been proposed by the Cyclone Resistant Infrastructure Development Project. These identify depths of potential inundation by storm surges as follows:

Hazard Class	Depth of water (m)
1	below 0.5
2	0.5-1.0
3	1.0-1.5
4	1.5-2.0
5	Greater than 2.0

2.3.3 Wind Risk Areas

Wind alone will be the prevailing hazard in areas inland from those affected by storm surges. As improved domestic construction can be made to withstand flooding of up to one metre and high winds, it is appropriate to consider this approach in

areas of Hazard Class 2 (below 1.0m)
areas of wind risk alone

Within these areas, improved construction could make possible:

continued occupation of homes during cyclones;
reduction in need for safe-havens;
avoidance of dangers between homes and safe-havens;
reduction of time away from home and attendant risk of theft;
Greater ability to use roofs of both kutcha and pucca dwellings as refuge during floods (designs should allow for this)
reduction of the recurrent costs of dwelling maintenance
reconstruction/replacement, enabling more people to stay safely in their own homes which will relieve overcrowding in safe-haven structures. This has been noted in the past as contributing to reluctance to use such shelters.

2.3.4 CGI Roofing

CGI (Corrugated Galvanised Iron) sheet has been used in the construction of domestic buildings for more than 150 years. It is used successfully in cyclone resistant construction elsewhere in the world (e.g., Lewis, 1991). It is becoming widely used in Bangladesh because of its convenience, as an expression of comparative wealth and because it is often distributed as a relief or reconstruction material after cyclones and floods.

Less constructively, cgi is recognised as having a long-term resale value. The sheets are liable to be redistributed among family members in the case of the owner's death or sold to relieve financial hardship. Either of these situations can thus initiate deconstruction of the dwelling and substitution with a material of lesser quality (though possibly one with less dangerous properties).

The distribution of roof sheeting for commercial or relief purposes should not occur without accompanying advice on cyclone-resistant fixing techniques. It is essential to improve fixing techniques for cgi and other metal, plastic or fibre-glass sheets to reduce damage from detached roofs and to protect the occupants.

2.3.5 Improved Traditional Construction

To be widely adopted, any modifications to traditional construction must be assessed for cultural as well as socio-economic acceptability. The wider contexts of population migration (both long-term and seasonal), flooding and cyclone-risk reduction, land tenure, credit access and development policies are all relevant to successful implementation.

Subject to regional availability, traditional materials are typically used as follows :

Floor	Frame	Walls	Roof
Mud plinth	Bamboo pole	Woven bamboo	Thatch
Raised timber	Jute poles	Mud	CGI sheet
		CGI sheet	

2.3.6 Siting and Layout

The siting of the scattered settlements of rural Bangladesh characteristically takes advantage of the slightest variations in ground levels. Trees (where existing) and buildings should be inter-related so as to protect each other.

Clustering helps to protect from normal winds and weather as well as from cyclones in a way that linear layouts do not. It also allows greater privacy with freedom of movement, especially for women. Supervision of children and animals is easier and security against looters (a particular requirement of relocated communities) is improved. For all these reasons, land allocated to housing projects should be sufficient to allow clustered layouts.

2.3.7 Plinth

Extreme care and attention is usually given to construction of the raised floor or plinth which is often the only remaining trace of a building after a flood. This can be constructed in excess of half a metre in height and thus protect the rest of the structure in Hazard Class 1 areas.

Improved plinth construction measures include better integration of the frame posts and improvements to the flood resistance of plinths in areas of sandy soils.

2.3.8 Frame

This is usually of *muli* or *talla* species of bamboo, possibly with jute poles for lighter members. Frame elements are commonly lashed together with jute rope.

Proposed improvements are :

treatment of bamboo against insect attack;
Treatment of poles against rot in the ground;
better anchoring of poles into the ground;
inclusion of cross-bracing; and
substituting galvanised wire binding for jute rope.

2.3.9 Walls and Openings

Walls are typically panels of split and woven bamboo or similar materials or cgi sheets. Wall panels commence within the mud plinth.

Proposed improvements are :

Place the door in the centre of the wall
Add a small window in the rear wall
Limit the areas of window openings in relation to walls.

2.3.10 Roof

The roof is usually either thatch or cgi sheet.

Proposed improvements are :

increase the pitches of roofs to 30 to 40 degrees;
encourage the use of hipped roofs;
tie down thatch;
use more frequent, improved fixings for cgi sheet; and
use methods for the permanent or temporary tying down of entire roofs (e.g., on receipt of cyclone warnings).

2.3.11 Survival of Cyclone-Resistant Kutcha Construction

It is necessary to establish the extent to which improved kutcha construction has survived in cyclones and reasons why traditional construction has failed. Case studies from the field are required. Traditionally, family belongings are stored by burial in the mud plinth of the house. This could be allowed for in construction of the plinth by, for example, incorporating a concrete box. Cyclone-resistant construction offers alternative options for domestic storage within the roof structure.

2.3.12 Tree Planting

Afforestation is referred to in the MPCS "Master Plan" as traditional accompaniment to dwellings in coastal areas, as it is throughout Bangladesh.
Trees provide :

- wind break
- impediment to waves and surge
- anchorage for people and dwellings
- high level platform bases
- ground stabilisation

Tree planting programmes on killas and embankments should be extended to settlements throughout the risk areas and planting materials made available for the purpose.

2.3.13 Improved Pucca Construction

Construction in pucca (permanent) materials such as brickwork and concrete block offers further important opportunities for improved domestic construction. Many more advisory studies have been undertaken for pucca construction than for traditional construction. This probably reflects an assumption that pucca construction is a prerequisite for cyclone and flood-resistance as well as the affinity of Dhaka-based or overseas donors for pucca rather than traditional methods.

It should be remembered that pucca construction requires improved building techniques to use its more permanent materials to their fullest advantage. Social and economic investment in the perceived security of pucca construction may otherwise result in greater, not lesser, losses.

Possible improvements in pucca construction include:

- the use of concrete in foundations and improved anchoring techniques
- the use of sawn timber and galvanised steel straps to tie roof structure members to each other and to walls
- improved fixings for roof sheets
- the provision of external timber window shutters.

An influx of non-traditional construction forms occurred after the 1970 cyclone and the War of Liberation in 1971. Projects proliferated to create flood- or cyclone-resistant domestic construction for "nucleus houses", steel-framed dwellings or for those with concrete posts and beams. Many initiatives were the results of alien preconceptions of need and usefulness originating outside Bangladesh. Few of the products were sustainable either as dwellings or as projects and were easily superseded as development assistance shifted to other priorities.

Successful technology transfer requires that the new technique be seen to serve a specific issue, to be of clear advantage, to follow traditional social and cultural forms and to be of low cost. One successful example was the introduction during the 1970s of polythene sheet used in bamboo mat "sandwiches" for roofing (Figure 2.15). Reinforced concrete "nucleus houses", built by the PWD (government's Public Works Department) at Urir Char, filled a specific need for "sentry" houses for guards who could prevent looting while others went to shelters. Unfortunately, poor site selection has sometimes negated the benefits as whole buildings have been swept away.

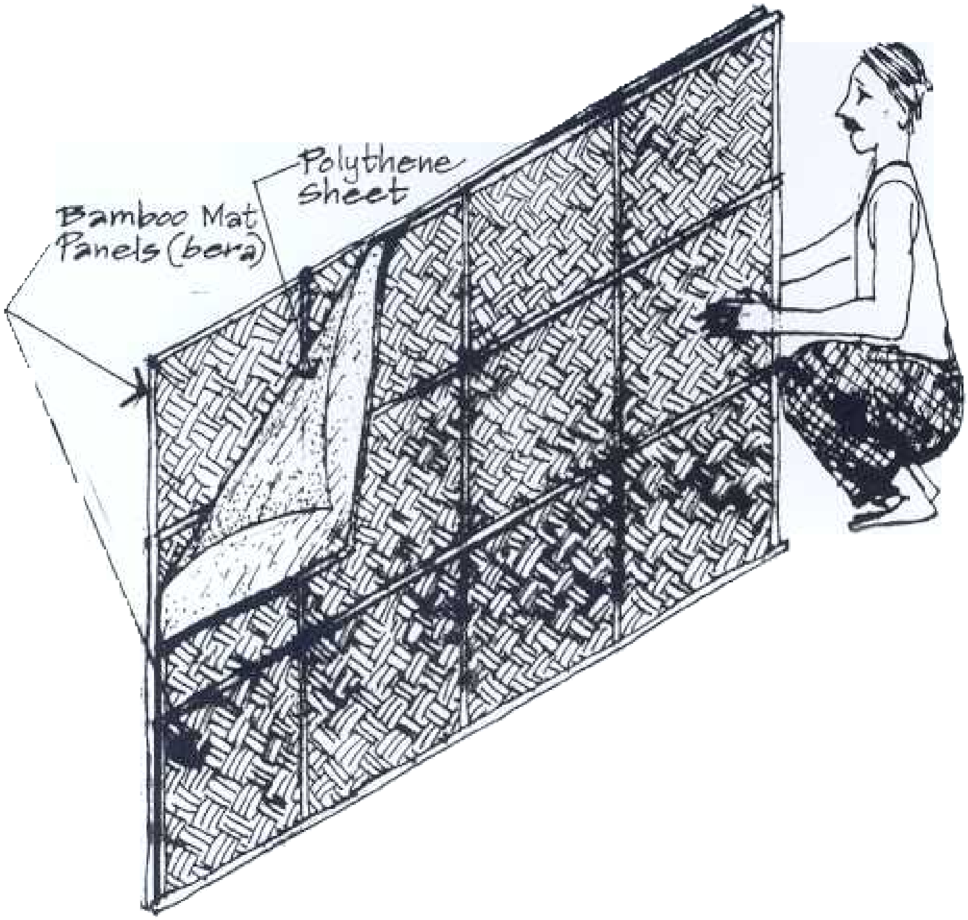


Figure 2.15: Polythene Sheet Used in Roof Mat Sandwich

2.3.14 Implementing Improved Domestic Construction

The cost of the proposed improvements to a kutcha bamboo dwelling would be of the order of 5% of its total cost and the same might be expected for upgrading a pucca construction. It is interesting to note that a study in Comilla in 1977 found that although the home represented 10% of its assets, the typical family spent only 2% of its income on maintenance.

Both Government and non-governmental agencies have provided various types of assistance with rural housing. These programmes, including loans for construction, house repair projects and construction of new buildings, have not always managed to target those rural landless households in most need. In any case, exercises in non-traditional const-ruction by-pass the real need which is for improved traditional construction.

2.3.15 Promulgating Improved Construction Technology

Traditional construction is undertaken by self-builders, possibly with help from neighbours and friends (other self-builders). This artisanal building is an aspect of local knowledge and is not in the purview of construction professionals or commercial contractors. Therefore, ways must be found to reach self-builders using methods more appropriate to this audience than conventional sources of information on construction technology.

Methods for technical improvement should be considered in their cultural, social, economic and practical contexts, including, for example:

training programmes for non-governmental organisations (NGOs) engaged in housing construction, repair and loan programmes so that their activities could be accompanied by the promulgation of improved traditional construction techniques;

promulgation by ngos would be through community groups and community development activities;

additional public information programmes should be mounted to spread information through newspapers and local news sheets;

the services of the mass media such as radio, television and cinema may be used for dissemination purposes.

demonstration projects with technical assistance in the field.

These activities would require the preparation of guidelines, leaflets and notices in Bangla and with graphic illustrations for distribution as public information programmes in advance of each cyclone season. Additional information leaflets should be prepared for promulgation through purveyors of construction materials, especially of corrugated roof sheets.

A series of participatory demonstration projects should be mounted to show the importance of house siting, juxtaposition and form and how various materials should be selected, treated, joined and maintained. These would provide the visual material for the preparation of videos to be used by NGO and others in community development programmes. All these activities should be either continuous or repeated annually.

2.3.16 Future Directions

Dwellings incorporating improved cyclone and storm-resistant construction are an important component of cyclone-resistant infrastructure development.

Improved domestic construction can be capable of resisting flooding of up to half a metre (Hazard Class 1) and cyclone winds of inland force.

Improved techniques for the fixing of corrugated galvanised iron roof sheets are required urgently.

Programmes for improved domestic construction should be considered in their cultural, social, economic and practical contexts. Such programmes should be:

- inclusive of tree planting;
- inclusive of both kutcha and pucca materials and methods;
- repeated annually or designed to be continuous.

Again, the present imbalance of funding in favour of pucca construction requires redressing to concentrate more on *kutcha* types; Roof construction must take into account its significance as shelter in times of flooding; The relationship between dwelling maintenance and cyclone damage needs to be addressed through training and information programmes; Post-cyclone field surveys of the modes of structural failure of kutcha construction are also required; finally long-term programmes, say of 25 years, are expected to be needed for effective promulgation, demonstration and absorption.

2.4 Building Design for Disaster Management

Bangladesh is prone to disasters such as flood, tropical cyclone, storm surge, tornados, river bank erosion, earthquake and arsenic. The country is particularly vulnerable to some of the world's strongest tropical cyclones. Death and loss of property from these cyclones are the highest in the world. Most government or external initiatives have traditionally paid little attention to addressing the underlying causes of vulnerability caused by cyclonic storm. Mostly management practice and modes of implementation are undertaken without due consideration to community dynamics, perceptions and priorities. Questions arise as to: a) how the affected people deal with disasters; b) whether these people are just passive victims and vulnerable beneficiaries of relief; and c) the existence of coping mechanisms developed historically by the people on which interventions can be planned for more sustainable disaster management.

The following two projects, built in the cyclone affected areas of Cox's Bazar, are discussed here:

a) COMMUNITY-BASED MULTIPURPOSE CYCLONE SHELTERS by the Development Association for Self Reliance, Communication and Health (DASCOH).
b) BATTLING THE STORM: A STUDY ON CYCLONE RESISTANT HOUSING by Community-based Disaster Preparedness Programme, Bangladesh Red Crescent Society / German Red Cross.

2.4.1 Community-Based Multipurpose Cyclone Shelters

Process oriented establishment of Community Based Multipurpose Cyclone Shelters (CMCS) were implemented by DASCOH. At the outset DASCOH identified the problems associated with the planning, construction, usage and management of cyclone shelters. DASCOH from the beginning prepared an organisational system to overcome these problems.

2.4.1.1 Organisational System

Communities were selected on their firm commitments in ensuring their willingness to donate sizeable land to construct the shelter. After selection of the intervention areas, the disaster preparedness needs of the community were assessed through Participatory Rural Appraisal (PRA) exercises. Through these exercises the community recognised the need and importance to organise into committees to decide on this usage, management, shelter construction and to collaborate with outside technical assistance in the planning, construction and management of cyclone shelters.

DASCOH undertook a feasibility study by engaging a Swiss engineer for the project. The engineer undertook a survey and assessment of existing and planned cyclone shelters. The final assessment adjusted the shelters by Prism Bangladesh to be the most appropriate design as it was considered harmonious, original and well suited for the project areas selected by DASCOH. Bashirul Haq & Associates Ltd, designer of the shelters built by Prism Bangladesh (Figure 2.16) was chosen to to prepare the architectural designs for DASCOH's project (Figure 2.17).

The requirements of the shelter were:

Figure 2.16: Community Development Center and Cyclone Shelter, Prism Bangladesh

1) School having 5 class rooms
2) Separate areas for men and women, when used as a shelter during cyclone
3) Separate toilets for men and women
4) Drinking water inside the building
5) Hand pump to be operated at the first floor
6) Shelter requiring least maintenance
7) Building design should generate a sense of pride in the community.

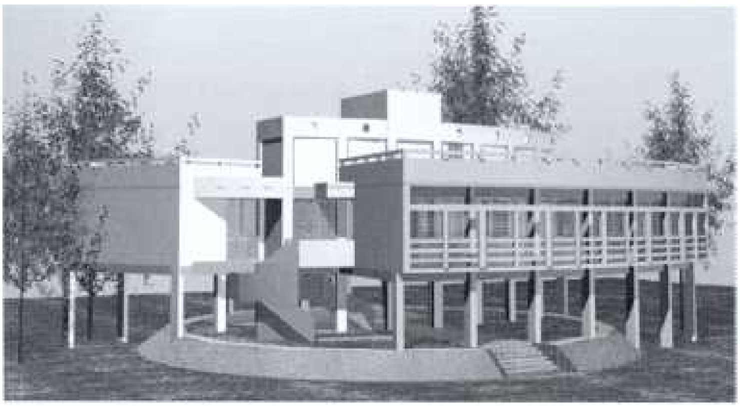


Figure 2.17: Cyclone Shelter For Development Association for Self-reliance Communication & Health (DASCOH), Bangladesh

2.4.2 Cyclone Resistant Housing

It is common knowledge that cyclone destroys a considerable number of houses in the affected areas. Further, this leads to increased risk of injury and the burden of reconstruction of houses. Combined efforts of Bangladesh and donor agencies to provide pucca houses that are cyclone resistant, at present, is financially prohibitive. Alternatively, indigenous technology and shared knowledge of the communities in home building, which has been effective in cyclone resistance and in combining local knowledge with easily applicable intervention of appropriate technology could be identified. This might contribute towards a mitigation of the destruction of houses. With this objective German Red Cross initiated a survey and study.

The survey was based on the premise that problems in housing should not be defined by experts only, but should be based on dialogue with local people of the target areas. Direct involvement of the local people in problem identification was ensured, so local perceptions, attitudes, values, shared knowledge, etc. could be taken into account.

The ideas (or methods) were: (a) to learn directly and by face-to-face encounters with local people, in order to incorporate technical know-how, as well as to learn about physical and social conditions; (b) to learn by listening to, and seeking from local people, their concerns and priorities about housing related problems; and (c) to use participatory assessment methods and activities for creating dialogues with local people for the collection of relevant information.

Participatory methods, techniques and tools included: 1) the collection and review of secondary sources (this included collection of *mouza*, *upazilla* and district maps); and 2) the preparation of a questionnaire, diagrams and scoring cards. These tools were used to ascertain wealth ranking and identity of house owners in order to prepare social mapping. Scoring cards were used in the survey to identify options, work ability and people's perceptions of safety, orientation, distance of the trees from the houses and structural weaknesses in traditional houses.

2.4.3 Graphical Presentation of Social Survey

This part of the survey was a graphical presentation of social mapping, location of selected houses and the identity and wealth ranking of selected house owners. The drawings were prepared with the help of the existing mouza maps of the study area. It allowed obtaining an understanding of the people, place and typology of houses (Figure 2.18).

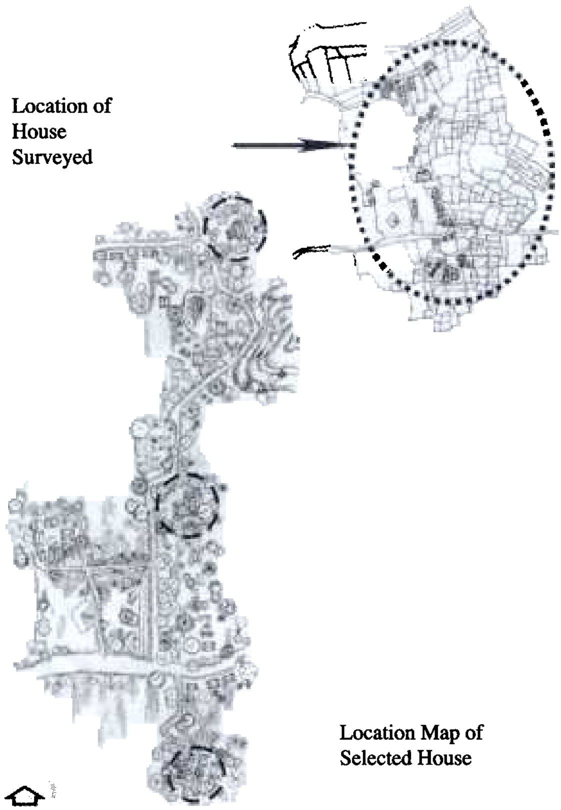


Figure 2.18: Graphical Presentation of Social Survey in One Area

2.4.3.1 Physical Survey of Selected Houses

Monographs of individual houses have been prepared through physical survey, measured drawings, sketches and photographs (see Figure 2.19. Each house was identified by its owner. The houses were chosen on the basis of findings of the survey, social mapping, wealth ranking and identity of houseowners.

2.4.3.2 Architectural and Structural Details of Houses

The houses surveyed can be termed indigenous houses. The term describes the art of building by anonymous local builders. The accent is on community enterprise in building produced by the spontaneous and continuing activity of people with a common heritage. Other terms used for these kind of houses are vernacular, spontaneous and rural. The builders show an admirable talent for blending the houses with the natural surroundings. The house plan, roof shape and orientation have developed in response to the climate, topography and available building materials of the area. The manner in which these materials are used and the development of structural features by the traditional builders to withstand harsh climatic conditions is surprising, as if the builders have anticipated systematic developments in building science.

Figure 2.19: An Example from the Physical Surveys of Houses

Materials alone do not make houses cyclone resistant, rather it is the manner in which these are used. The competence of local builders is evident in their understanding and ability to identify certain structural features which are particularly susceptible to wind damage. These features are in the roof structures, extra support of the roof ridge, the tie between roof structures and vertical support, and the need for extra ties for extended roof overhangs. Further, the awareness of builders of the need for strengthening traditionally built structures is evident when we look at their use of metal strap between wooden post and joist and the use of strong and durable nylon rope for tying bamboo sections.

The main weakness of many of these houses is the fact that the foundation is not firmly anchored to the ground. This causes houses to be lifted up or blown away by cyclones. Another major weakness is the fast deterioration of traditional building materials like bamboo, as these are not protected against decay, fungi, termites and high humidity when in contact with the ground.

2.4.3.3 Technology Intervention in House Building

A sizeable number of local people are unable to undertake safer construction of their houses for lack of capital and high cost of building materials; they cannot afford the cost of re-building after severe damage due to cyclone. This is reflected in the survey of people's perception of the most important problems in housing. The technology intervention in house building at present is limited only to strengthening the structures for cyclone resistance by using pre-cast concrete post, steel truss and corner bracing. This house form disregards the traditional house typology, roof shape and lifestyle of the local people, which is the cause of rejection of the proto-type houses introduced by several organisations.

2.4.4 Specific Case of Technology Intervention

BDRCS with assistance from the International Federation of Red Cross and Red Crescent Societies initiated the design and building of a prototype house: "The Wind Resistant Hut". The structure of this house type has pre-cast concrete columns for vertical support, steel truss for roof support and steel rod for bracing between columns. Bamboo mat is used as wall. Problems with this house type arise not with the details of anchoring to foundation and jointing details of truss to vertical post, but the use of steel sections for fabrication of truss, roof shape and most importantly in the lukewarm response in acceptance by the beneficiary (Figure 2.20).

2.4.4.1 Transformation of the Wind Resistant Hut

Steel sections for fabrication of truss in marine weather require application of properly specified paint and regular maintenance. Fabricated steel sections as building materials are inherently more complicated for repair and maintenance, particularly in a low technology area where people depend on local expertise and locally available materials. Experiments have shown that houses with hip roofs have the best record of resistance to wind loads. The roof shape of the BDRCS house type is gable roof with 27.5^{o} pitch, where the recommended gable roof in cyclone affected areas is 'high gable' roof with pitch between 35^{o} to 45^{o}. The traditional houses in these areas have a room surrounded by *pashchati (verandah)*. The roof shape of the roof over the room is invariably hipped and the *pashchati* roof is separated from the hipped roof. Because of this separation, *pashchati roof* usually suffers wind damage without affecting the roof of the ghar. The *pashchati* area, beside creating extra space for entertaining guests, eating, cooking, sleeping, etc., also acts as a barrier during cyclones accompanied by heavy rain. Further, its low roof creates a sense of protection and privacy.

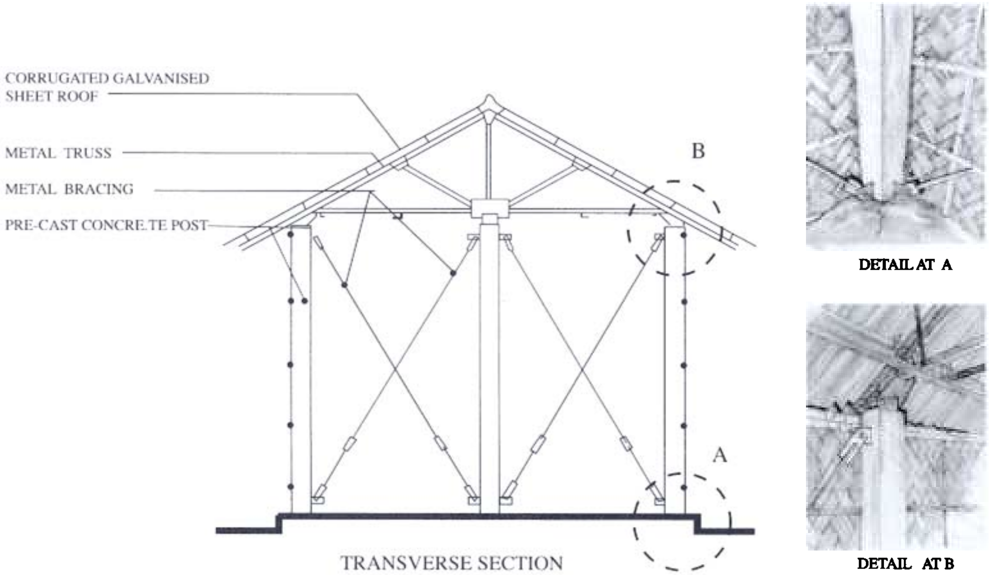


Figure 2.20: BDRCS 'Wind Resistant Hut'

The photograph of the house in Figure 2.21 shows the transformation of a BDRCS initiated house type. The roof of the BDRCS house type is visible within the present house form shaped by addition and alteration in order to suit the lifestyle of the beneficiary living on Moheshkhali island.

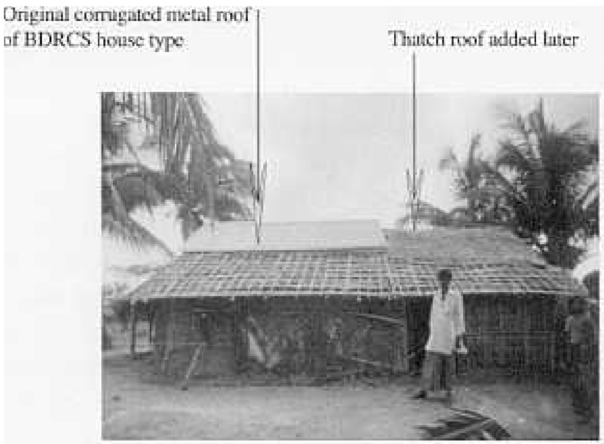


Figure 2.21: House at Charpara, Moheshkhali

2.4.5. Building Materials

The materials used in the houses are predominantly bamboo or wood for vertical support, joist and truss for roof support. Walls are either of bamboo mats or wood planks. Bamboo is used in houses that belong to households with low economic ranking, and wood is used in houses belonging to those of moderate level ranking. Technology intervention in house building has introduced steel and pre-cast concrete sections into a few houses. Use of bamboo as a building material requires a high level of maintenance or frequent replacement because they are of poor quality and not treated with preservatives. As such, the material is not protected against decay, fungi, termites, marine bore attack and high humidity when in contact with the ground. Decay, fungi and termite attack are less visible in houses built with wood sections. This may be due to better maintenance and use of good quality and appropriate species of wood that is safe from termite and marine bore attack.

The steel sections used in some of the houses were already rusting. Steel used in the marine area requires special undercoats and regular maintenance, as observed in shelters built in St. Martin's Island, where steel windows have rusted badly over the years due to lack of proper undercoat paint and maintenance.

Pre-cast concrete pillars were used for vertical support in some houses. Quality control of materials and fabrication of pre-cast concrete pillars are important for strength. During the survey a number of broken and twisted concrete posts were observed in one location, which had failed structurally during the cyclone of 1994. There are examples of innovative use of materials in some houses, such as the use of a combination of wood, bamboo and pre-cast concrete posts.

2.4.6 House Typology

Cyclonic storm and high wind seems the most obvious factor in the development of the form and shape of these houses. The magnitude of wind loads on the structure influences the roof shape. Experience and experiment have shown that houses with hip roofs have the best record of resistance. During a cyclone, large pressure builds up under the overhang, and this pressure added to the suction on the upper roof can pry it away from the walls. This problem has been solved by keeping a minimum roof overhang in most houses and a separation between the roof over *pashchati* from the main roof of the house.

In order to reduce high pressure on the internal surfaces of the wall, the indigenous houses are built with only one opening, which can be securely closed at the time of cyclone. The wall around the pashchati, particularly in the case of bamboo mat wall, helps in reducing water penetration affecting the ghar during gusty wind accompanied by heavy rain. The main cause of wind damage on the houses, particularly houses built with bamboo sections, is the insufficient weight of these houses when they are subjected to external pressure and suction on the walls during cyclone. This can be rectified or even avoided by improving the anchoring of the vertical support firmly to the foundation. The case study that follows shows how indigenous housing can be modified to withstand harsh climatic conditions.

2.4.7 Case Study: House that Survived

The worst cyclone in the memory of local people of one of the study areas in recent times was in 1994. During this cyclone the house belonging to a wealthy person became a shelter for hundreds of women and children of the surrounding areas, because local people felt confident that the house would withstand the cyclone as it had withstood previous cyclones. It has been observed in the cyclone affected areas that there is less likelihood of a house being damaged or destroyed if the roof structure of the house is strong and secured to the vertical support system which is firmly anchored to the foundation.

This house was located in an area surrounded by trees and other houses that act as wind breaks. The roof supporting system was fabricated with wood sections of standard quality and size. High level of competence in joinery details, and the use of steel angles, bolts and screws for tying and fixing the different members of the roof structure and the vertical wooden posts made the house very strong and cyclone resistant. The house was selected as a case study because it was built with local building materials and by a local builder.

2.4.8 Preservative Treatment of Traditional Building Materials

Surveys and interviews were conducted in order to obtain information on locally available methods, availability of expertise and, above all, effectiveness of preservative treatment. Technology availability and its effectiveness for improving and enhancing durability, particularly of bamboo, is a very important aspect of the recommendations of this study.

This technology could be potentially significant, looking at the use of untreated bamboo in houses of the survey areas. The durability of untreated bamboo is only 2-3 years, as bamboo is constantly subjected to attack by insects, fungi, termite and when in contact with moist ground. Experts from the Bangladesh Forest Research Institute (BFRI) and Bangladesh Agricultural Research Council (BARC) were interviewed, and information, literature, etc. on the preservative treatment technology developed by BFRI were collected.

BFRI built a house using treated bamboo, wood, sun-grass, etc. in 1983. This house demonstrates the effectiveness of the need and the critical aspect of the preservative treatment. There was no sign of decay or attack by fungi, insects and termites on the treated building materials even after all these years.

2.4.9 Construction Techniques, Structural Components and Details

The purpose of recommendations on construction techniques, structural components and details is to create an understanding and awareness among local people, organizations involved in house building and local builders to improve cyclone resistance of traditional houses. The survey and study have already identified weak points in design considerations, social and environmental problems, building materials, architectural and structural details of houses. Here the weaknesses of construction techniques, structural components and details in the manner in which the houses are built are presented, and solutions and guidelines to strengthen structural components and details for cyclone resistant houses are suggested. Sequence of construction of a house consists of foundations, floor finishes, walls and openings, roof structures and roof cladding. The illustrated details are typical and not for constructing a particular proto-type house.

2.4.10 Guidelines for Cyclone Resistant Houses

2.4.10.1 Layout and Orientation

In most cases, the layout and orientation of traditional houses are in such a manner so that the shorter face of the house is towards the windward direction of the cyclone.

2.4.10.2 House Plan

The best plan shape is a square or a rectangle for wind resistance. The traditional houses in these areas are mostly rectangular with length and width ratio within 2:1. It may be mentioned here that length to width ratio up to 3:1 is generally recommended for cyclone resistant houses.

2.4.10.3 House Roof Shape

The traditional houses have hip roof over the ghar and a very low roof over the pashchati which is separated from the hip roof. Experience has shown that this type of roof has the best record of resistance during cyclone (Figure 2.22).

Figure 2.22: Roofing of Traditional House

2.4.11 Social, Economic and Environmental Considerations

2.4.11.1 Socio-Economic Problems

People's perception of problems in housing have been gathered through the survey conducted in six different locations in Cox's Bazar District. The problems identified in order of importance are: cost of re-building and repair after a severe cyclone, lack of capital, cost of materials and lack of technical knowledge of building construction.

2.4.11.2 Environmental Problems

It was possible to identify through people's participation the environmental problems related to housing. These problems are: a) cyclone, b) tidal surge, c) finding safe location for house building, d) plantation of trees as wind breaks to reduce the impact of cyclone on houses, and e) distance of trees from houses.

A proper plan for plantation of trees helps reduce the impact of both cyclone and tidal surge. Tree plantation should be undertaken by participation of local people for appropriate selection and location of trees and plants.

2.4.12 Indigenous Building Materials

2.4.12.1 Bamboo and Wood

Wood and bamboo is extensively used in construction of indigenous houses. Wood used in most houses is of very poor quality. This results in shrinkage and warpage, causing susceptibility to fungal attack. Besides, bamboo members should be treated with preservatives to enhance their durability. At present both wood and bamboo are used without treatment by appropriate preservatives.

2.4.13 Steel Sections and Pre-Cast Concrete Members

Steel sections have been introduced through technology intervention in a few houses for fabrication of truss and strengthening of structural members for tying and fixing. When steel sections are used in marine and salty atmosphere, there is need for ensuring quality control of materials, proper surface preparation and application of specified undercoats. Undercoats should be carefully selected for suitability in marine weather.

Precast concrete members have made inroads as a building material into the local house building trade. The members are primarily used as vertical support. Problems at present consist in quality control of materials and methods of fabrication. Besides, there are no well thought out tying and fixing details incorporated during fabrication of the pre-cast post. It is possible to use pre-cast sections as beams to support wood or bamboo rafters. The roof joist can also be of pre-cast concrete.

2.4.14 Foundations

Bamboo and wood sections should be selected on the basis of appearance and strength. Bamboo should be treated with appropriate preservatives. The foundation should be in accordance with the details in Figure 2.23 in order to improve anchoring of the vertical support firmly to the ground, giving sufficient stability to the house.

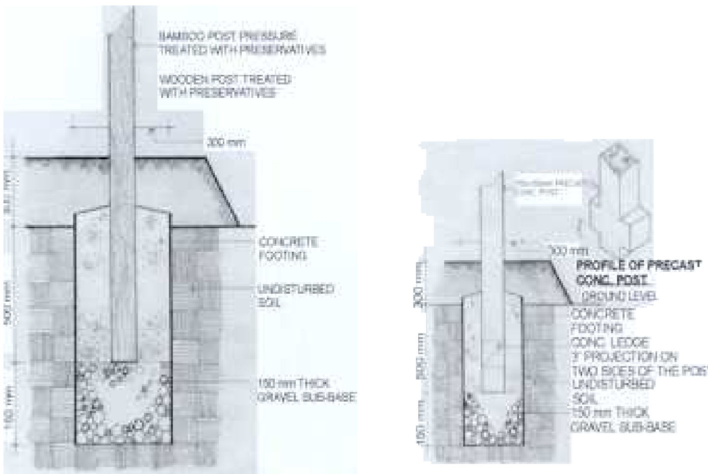


Figure 2.23: Typical Footing for Timber or Bamboo Post

2.4.15 Flooring

Most of the houses had mud floors, but a few had concrete floors. Floor levels of many of these houses, particularly houses belonging to people of very low economic level, were almost at the ground level. The woven bamboo mat walls in these houses were buried into the soil presumably to prevent entry of frogs, snails, insects, reptiles, etc. into the houses. These walls deteriorate very fast due to constant contact with the moist ground and being subjected to fungi, termite and insect attack (Figure 2.24).

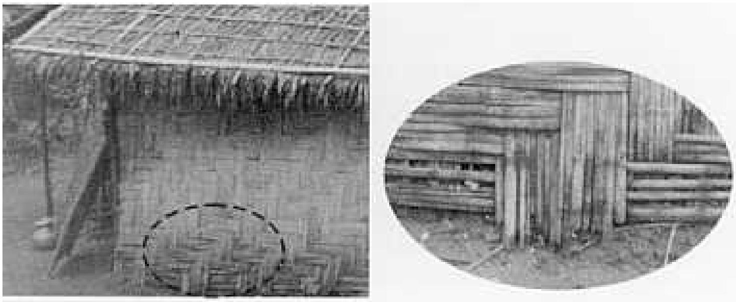


Figure 2.24: Walls Deteriorating in Contact with the Ground

2.4.16 Walls

Wind is resisted by woven bamboo or timber board sheathing and vertical supports. Diagonal bracing should be used to strengthen the walls, and to reduce the chances of corner failure due to unequal pressures on two side walls during cyclones (Figure 2.25). For construction techniques and details, the expertise of local builders for spacing of vertical bamboo posts and fixing and tying of woven bamboo sheathing to posts can be relied upon.

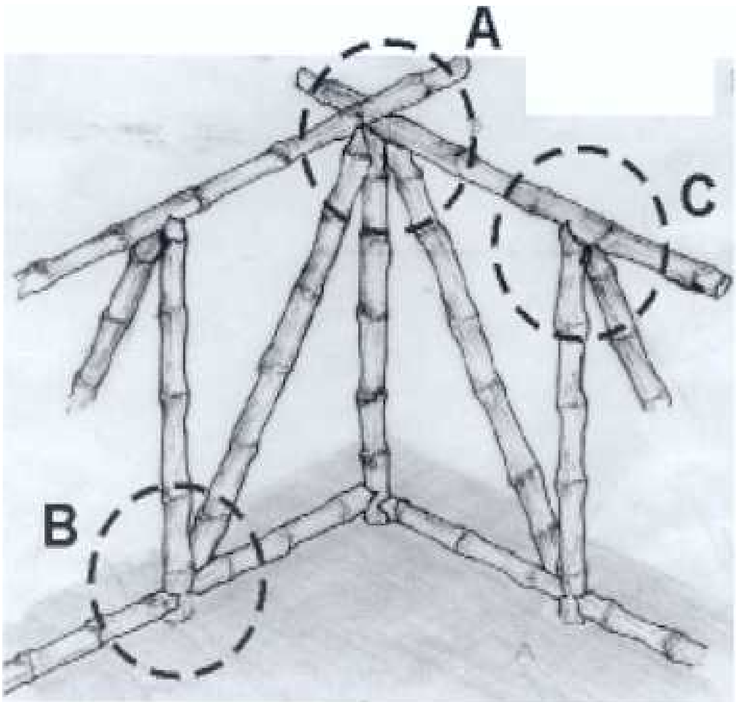


Figure 2.25: Corner Bracing

If the roof structure is secured firmly to the vertical support system there is little likelihood that the house would be damaged by cyclone. Recommendations should focus on bamboo and thatch as building materials for roof structures and roof cladding. The reason is that bamboo is the most extensively used building material. The roof structure of most of the houses in the study areas were built with bamboo.

2.4.17 Roof Structure and Cladding

2.4.17.1 Roof Structure

The roof structure consisted of horizontal bamboo support members (beams) supported by bamboo posts. The bamboo beams supported rafters of split bamboo. In the roof structure system, the most important connections were that between beams and vertical support and between rafters and beams. In order to make houses cyclone resistant, these connections should be strong to withstand the powerful upward force of the cyclone (Figure 2.26). Metal straps, commonly known as 'hurricane straps', may be used in the connections, particularly between post and beam. Local technology for connection details between beam and rafter is by tying the rafter firmly to the beam by nylon rope after cutting a notch in the rafter. In a better constructed structure, the notch in the rafter is securely fitted to the beam, maintaining the required slope. In terms of cyclone resistance the use of 20 gauge galvanised metal straps, nails, nuts and bolts along with the use of local materials such as nylon rope can be recommended (Figure 2.27, Figure 2.28).

2.4.17.2 Roof Cladding

In addition to the roof structure, the thatch roof cladding must be able to transfer wind loads to purlins. The eaves and the ridges of the roof are particularly susceptible to wind pressure during cyclone. Purlins, therefore, are important structural members of the roof structural system. Local builders use lattice bamboo slats having gaps of 200mm to 250mm between two slats. The latticed slats are fixed to purlins to protect the thatch roof from uplift during cyclones. The existing construction technique of roof cladding is well thought out, and in most cases, built well.

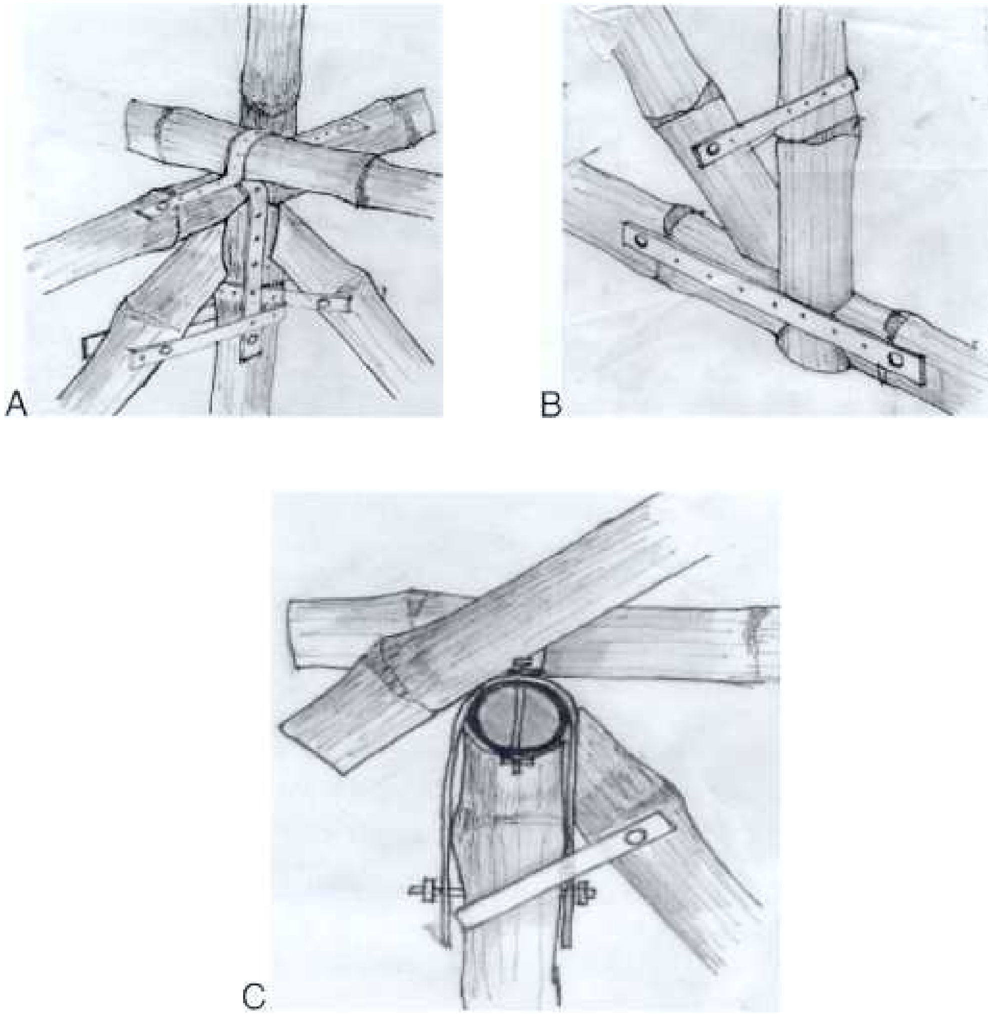


Figure 2.26 : Roof Structure Details

2.4.17.3 Fixing of C.I. Sheet Roofing

Spacing of purlins and the length of C.I. sheets should be adjusted so that the joints of the sheets fall on a purlin. The sheets are fixed from the top of corrugation with screws. Generally cotch screws are used with wood purlins and galvanised metal crank bolts with steel purlins. These screws are used with appropriate cup washers.

2.4.18 Construction Technologies for Wind Resistance

Observations made on Bangladesh's southeast coast suggest that cyclone resistance can be enhanced in traditional buildings by using a combination of architectural and innovative construction technologies.

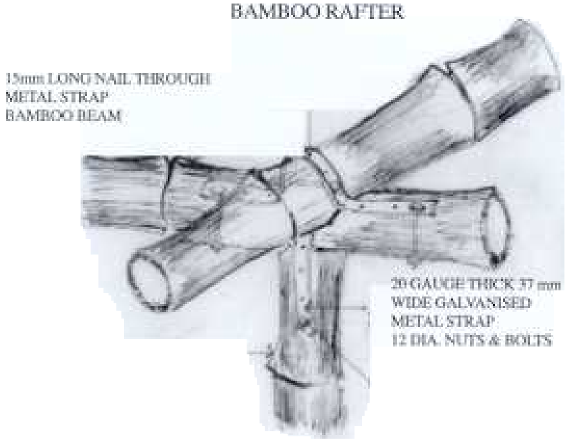


Figure 2.27: Fixing Detail between Post, Beam and Rafter.

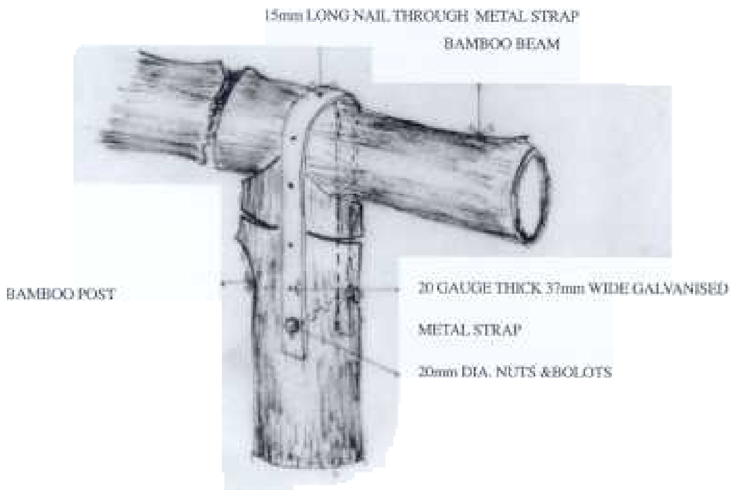


Figure 2.28: Fixing Detail between Post and Beam

Construction features that enhance wind resistance include:

1. A square floor plan
2. Hipped roof design
3. Additional support for the roof ridge
4. Use of appropriate preservative treatments to prolong lives of bamboo and thatch elements
5. Use of concrete footings for posts
6. Use of metal straps to fix bamboo joints rigidly

The Bangladesh Forest Research Institute built a house using these and other methods which has lasted very well, demonstrating the efficacy of these methods.

2.5 Effect of Wind on Rural Housing

Experimental investigation has been carried out in a wind tunnel on three different types of models of rural Bangladeshi houses. Tests were conducted by placing models of houses at different horizontal angles on a sliding platform and subjecting it to wind flow of different speeds and measuring the total thrust on the model produced by the wind. The tests were carried out to study the effect of different conditions of door and window openings, effect of the presence of verandah and the behaviour of the models in presence of different types of windbreaks. The study reveals that at high wind speed keeping the doors and windows closed or open does not produce significantly different results. The presence of verandah increases wind thrust on two types of model but decreased the thrust on the third type. It has been found that due to the occurrence of wind jetting, the effectiveness of trees as windbreaks is reduced. Solid wall type windbreak has been found to be most effective in reducing the wind thrust on models. These findings could contribute towards improvement of skill and practices of construction of wind-resistant rural houses in Bangladesh.

Recurrent occurrence of strong cyclones and loss of lives and property in the southern part, as well as other regions of Bangladesh, is well known. Construction of a number of cyclone shelters and coordinated cyclone alert system is in effect in these areas, and these measures are somewhat successful in preventing loss of human lives and livestock. Apart from this, no measure is taken to reduce loss of the household properties. The majority of people in this area belongs to the poorest section of society whose standard of living is far below even the limit of poverty. Local people without any formal engineering knowledge build the large majority of houses in these areas. According to a report (Lewis and Chisholm, 1996), about half of these houses is temporary in nature. These can seldom survive against even moderate intensity of storm. The houses are built of the cheapest construction materials like bamboo poles, woven bamboo, mud and thatch. Almost every year these have to be rebuilt after devastation by storms. When the long-term effect is considered, these houses turn out to be costly as a result of rebuilding them almost every year. It is thus felt that there is a strong need of more engineering knowledge to improve the construction quality of the dwellings in these storm-prone areas.

Within the framework of local construction practices, wind resistance properties of rural vernacular houses may be improved if some engineering judgements are applied on the basis of their behavior under wind. Such types of houses in the rural areas of Bangladesh are not covered in any design codes. Although there are some studies (Anwar, 1996) on improving the lateral load resistance characteristics of such rural houses, apparently no scientific database on the behaviour of these specific types of houses during strong wind is available. With the objective of understanding the behaviour of rural vernacular houses in Bangladesh, a series of wind tunnel tests on scaled down models has been performed in the recent past by a number of researchers. Ansary et al. (1999) and Ansary et al. (2000) performed an extensive study on the wind pressure distribution around a 1:20-scale model of a rural house. It was performed under various conditions of incident wind angles, roof pitch, presence of openings, etc. It revealed that pitch angle between 25°-40° was better against wind resistance. The pressure distribution measured at some critical locations has enabled identifying the most vulnerable points in a rural house structure. Roy et al. (2000a, 2000b) conducted another extensive study on models, including studying the failure characteristics of the model bamboo framework under various structural configurations. This study supported the fact that introduction of some sort of bracing system to the common bamboo frame structure significantly improves its resistance against wind forces.

The research presented here is a sequel to the above mentioned studies. A series of investigations have been undertaken to study the behaviour of different roof patterns, the effect of having an open verandah and effectiveness of different types of windbreaks.

2.5.1 Experimental Setup and Description of Models

Experiments were conducted in a wind tunnel at the School of Engineering, University of Exeter, UK. The wind tunnel is an open circuit type and has a working section 500mm high, 750mm wide and 1500mm long. The maximum wind speed of the tunnel is 35 metre/second. The wind tunnel is shown in Figure 2.29.

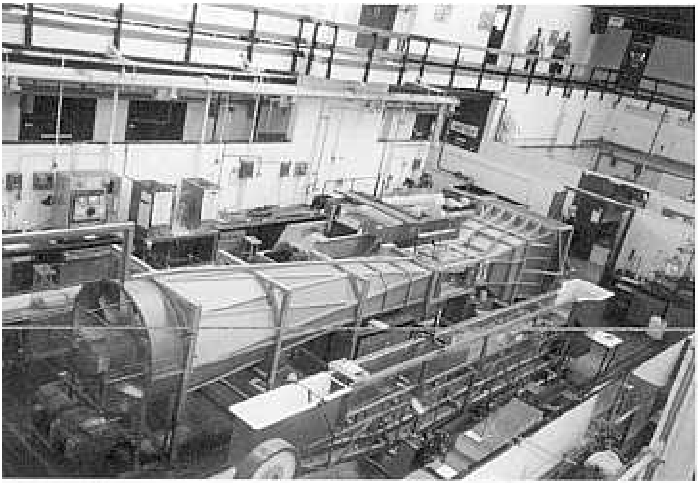


Figure 2.29: Wind Tunnel used in the Study

Figure 2.30: Type of Models under Study

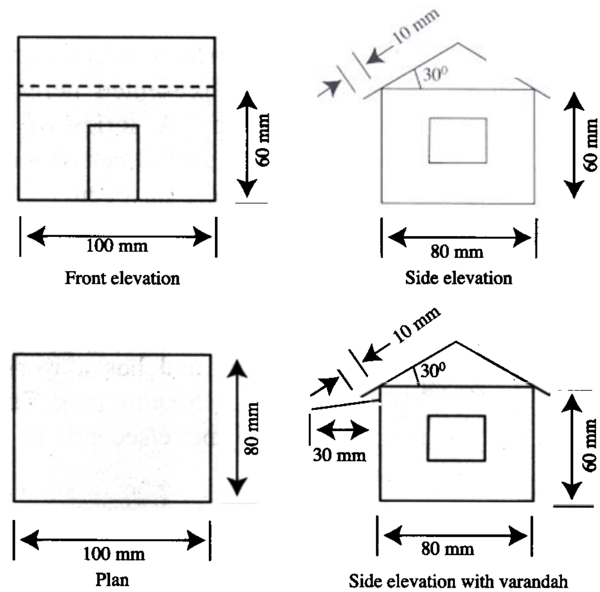


Figure 2.31: Typical Dimensions of the Model (shown with the Do-chala Type)

Three types of roof patterns were studied as shown in Figure 2.30:

Ek-chala or *Chapra:* The roof of this type of house consists of a singly sloped roof made of thatch or C.I. sheet. This type of roof is common among the poorest people. The pitch angle for the experiment was chosen as 10 degrees.

2. *Do-chala:* This is a typical house with pitched roof as shown in Figure 2.31. The slope of the roof is in two opposite directions. The pitch angle for this type of roof was chosen as 30 degrees.

3. *Chou-chala:* This is another type of typical house with pitched roof in which the slope of the roof is in all four directions. The pitch angle was chosen as 30 degrees, similar to the Do-chala type.

The models used in the present study are approximately at 1:50 scale of typical rural houses of Bangladesh. Each type of model was studied with a verandah, as well as without a verandah.

2.5.2 Description of Windbreaks

The effect of the presence of different kinds of barriers was also studied. Three types of barriers against the wind were considered:

1. Solid wall: Although construction of a solid wall around a house is not common in Bangladesh, it was included in the study for academic interest. The height of the wall was approximately 30mm.

2. Hedge: This is a more common type of barrier surrounding the houses. Properly planted and supported hedges can provide significant barrier against wind. The height of the hedge was approximately 35mm.

3. Tree: Trees provide good protection against wind. But there is no quantitative assessment on how much the level of protection is. The level of protection offered by trees was investigated. In this study, the height of trees was approximately twice the height of the models.

2.5.3 Measurement of Wind Force

In previous studies, the effect of wind was studied by measuring pressure at different locations. Although such measurements are useful in understanding the local characteristics of wind pressure distribution, such measurements do not give an idea of the total thrust on the model generated by the wind. Calculation of the total wind thrust from pressure distribution only at certain locations is difficult. Estimation of such kind of quantities is important in assessing the relative behavior of different kinds of roof patterns with or without the presence of verandah, the influence of windbreaks, etc. Thus, in this study was decided to measure the total wind thrust on the model instead of measuring pressure at different locations. This was done by placing the model on a movable sliding platform and connecting the platform to a spring fitted LVDT. A picture of the test arrangement is shown in Figure 2.32. The LVDT was, in turn, connected to a computer-controlled data logging system. The spring fitted LVDT was calibrated so that the displacement data signal sent to the data logger could be converted to force data by the controlling PC based on the stiffness of the spring. The whole arrangement was shielded by placing paper boards at the level of the platform, so that when the model was placed on the platform, the wind produced thrust only on the model, but not on the platform. Thus the platform slid due to wind thrust produced on the model only. This is shown in the Figure 2.33 (a,b and c).

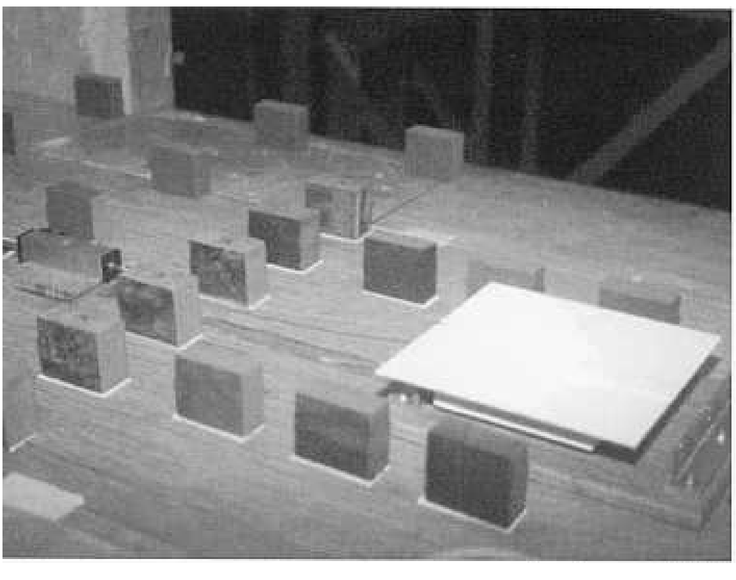
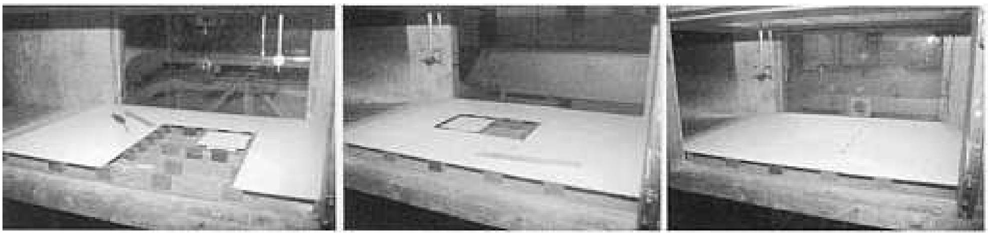


Figure 2.32: The Arrangement of Sliding Platform, LVDT, etc.



(a) (b) (c)

Fig. 2.33: Shielding the Sliding Platform and LVDT

2.5.4 Measurement of Wind Speed

A Pitot tube connected to a calibrated electronic micro-manometer measured the wind speed. The calibration was done by comparing the pressure measurements of the micro-manometer and the same from an inclined water column.

2.5.5 Boundary Conditions

The pattern of wind flow during an actual storm is quite different from that of a wind tunnel. Proper simulation of a storm requires that both the model and the flow be geometrically, aerodynamically and thermally similar. The conditions existing in a wind tunnel may be different from those that exist in a real storm. The results of wind tunnel tests must be interpreted in the context of these limitations. It is generally understood that, despite the differences, tests using a wind tunnel enables us to gain a fairly good idea about the behavior of real structures subjected to a real storm.

2.5.6 Experimental Results

Experimental investigation was carried out to study the effect of different parameters, such as the effect of wind incident angles, effect of presence of verandah, effect of keeping the doors and windows open or closed, etc. In the following sub sections, these matters are discussed in more details. A picture of the Chou-chala model (with verandah) under test is shown in Figure 2.34.

2.5.6.1 Effect of Wind Incident Angle

The effect of wind incident angle was studied for all model types. The test was performed by positioning the models on the sliding platform at different angles at an interval of 30 degrees and then subjecting it to different wind speeds. Recognizing the symmetry, the study was performed for angles of 0 to 180 degrees. Here, 0 degrees incident angle means wind hitting directly the front side (the side with door) of the models. The test was carried out for different conditions of door and window openings.

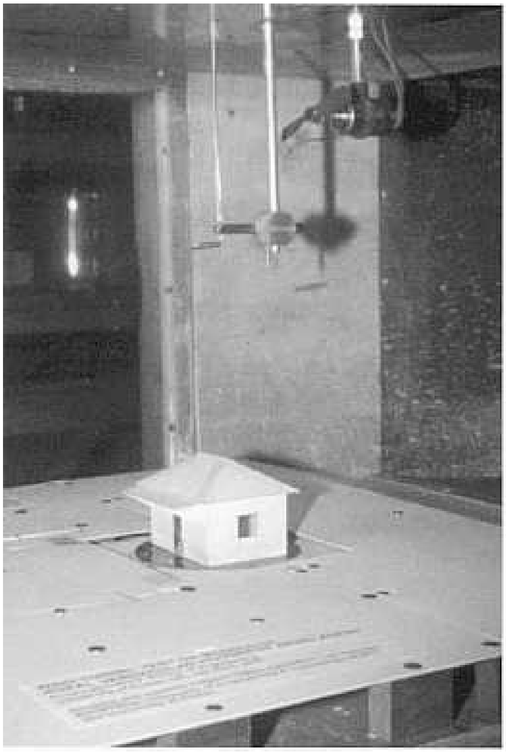


Figure 2.34: Chou-chala Model under Study

Figure 2.35 shows the behaviour of the Do-chala model. It was observed that at low wind speed, the model catches more wind for incident angle of 90° when the doors and windows are all open. When the openings are fully or partially closed, the maximum thrust occurs at an angle of about 30 degrees. However, for higher wind speeds as shown in Figure 2.35c, the maximum thrust occurs at an incident angle of 30 degrees when the openings are fully or partially closed.

Figure 2.36 shows the results for Chou-chala model. It was observed that for all-closed or all-open conditions of the openings the behaviour is similar. Maximum thrust occurs at an angle of approximately 30 degrees while the minimum force develops at the incident angle of 90 degrees for all magnitudes of wind speeds. In general, the all-closed condition of openings produces smaller thrust than the all-open condition, as seen in Figure 2.36.

Figure 2.37 depicts the behavior of the Chapra model. Unlike the previous two cases, this model developed maximum thrust at 0 degrees incident angle of wind. However, similar to Chou chala model, minimum thrust is produced at 90 degrees angle.

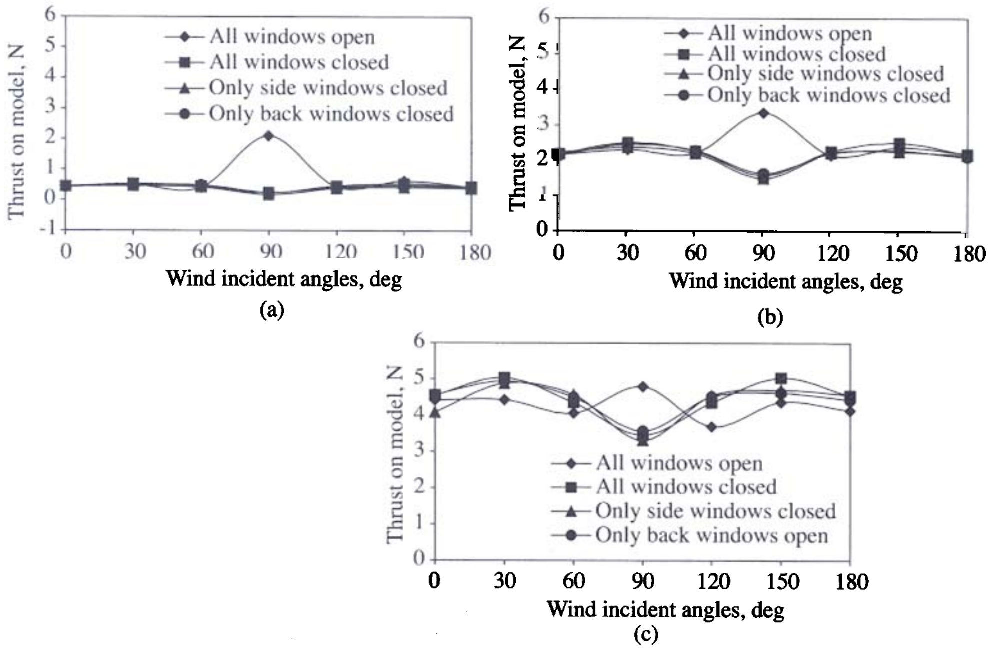


Figure 2.35: (a) Wind Force on Do-chala Model without Windbreaks at 10 m/s Wind Speed (no verandah) (b) Wind Force on Do-chala Model without Windbreaks at 20 m/s Wind Speed (no verandah), and (c) Wind Force on Do-chala Model without Windbreaks at 30 m/s Wind Speed (no verandah)

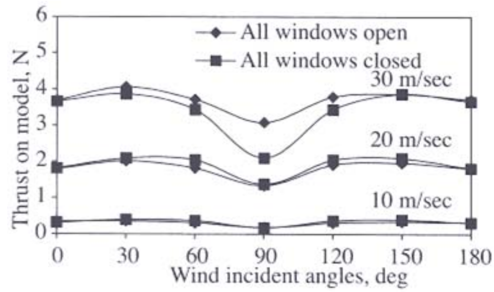


Figure 2.36: Wind Force on Chou-chala Model without Windbreaks (no verandah)

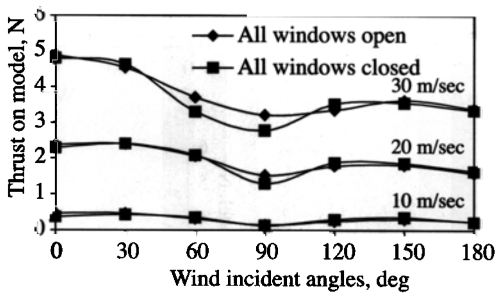


Figure 2.37: Wind force on Chapra Model without Windbreaks (no verandah)

2.5.6.2 Effect of Presence of Verandah

The effects of the presence of a verandah are shown in Figures 2.38, 2.39 and 2.40, for the models of Do-chala, Chou-chala and Chapra, respectively. For the Do-chala model the presence of verandah produces more wind thrust for all values of wind incident angles and the increase in the wind thrust is higher between incident angles of 0 to 90 degrees. For the Chou-chala model wind thrust increases for wind incident angles from 0 to 75 degrees and from 120 to 180 degrees, while the thrust decreases for incident angles between 75 to 120 degrees. However, the overall change in the thrust due to the presence of verandah is not as significant as that of the Do-chala model. The effect of presence of verandah is quite significant for the Chapra model. It can be observed from Figure 2.40 that the presence of verandah actually lowers wind thrust for wind incident angles of 0 degrees to about 45 degrees, after which the thrust is higher for angles up to 90 degrees. Afterwards, the difference in conditions between 'with verandah' and 'without verandah' diminishes.

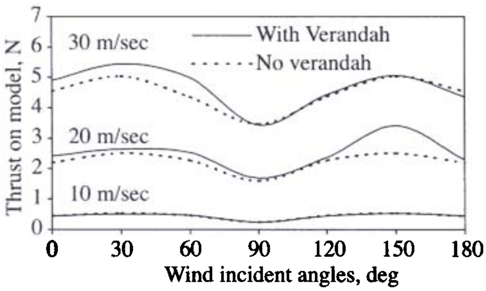


Figure 2.38: Wind Force on Do-chala Model in Presence of Verandah without Windbreaks (windows closed)

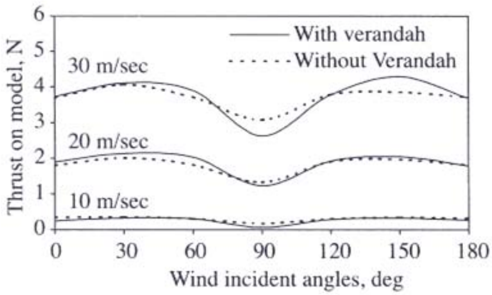


Figure 2.39: Wind Force on Chou-chala Model in Presence of Verandah without Windbreaks (windows closed)

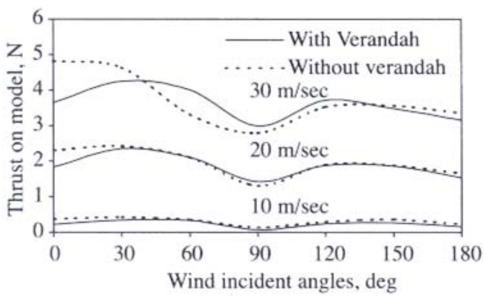


Figure 2.40: Wind Force on Chapra Model in Presence of Verandah without Windbreaks (windows closed)

Since wind can hit a house from any angle in a real life storm, it is important to study the maximum thrust produced by wind. Figure 2.41 compares the maximum thrust produced on the models. It was observed that the presence of a verandah increases the wind thrust for Do-chala and Chou-chala by about 10%, while for Chapra, the addition of a verandah actually lowers the thrust by the same amount. The overall magnitude of wind thrust is lowest for Chou-chala and highest for Do-chala.

2.5.6.3 Effect of Windbreaks

Windbreaks such as trees have been long regarded as an effective measure to protect a house from storms. However, it appears that there is not sufficient data to assess the effectiveness of such windbreaks in protecting typical Bangladeshi rural houses against cyclonic wind. Tests were carried out to investigate the effectiveness of three different types of windbreaks - trees, hedges and solid wall. The experiment was carried out with the Chapra model. Models of trees and other barriers were placed across the wind at a distance approximately equal to four times the height of the model. Figure 2.42 shows the Chapra model with a row of trees barrier.

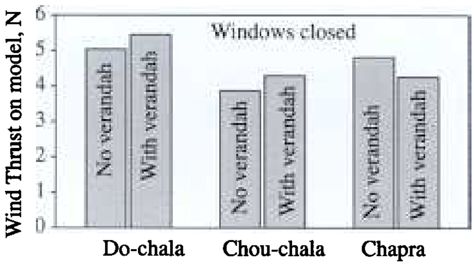


Figure 2.41: Effect of the Presence of Verandah on the Maximum Wind Thrust on Model at 30 m/sec Wind

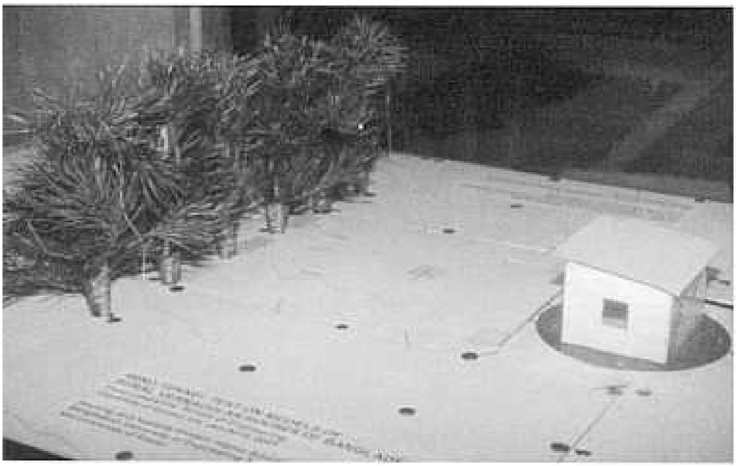


Figure 2.42: A Chapra Model under Study with Tree Barrier

Experimental results from testing the Chapra model with the different kinds of barrier are shown in Figures 2.43 and 2.44. Figure 2.43 shows the effect of gradual increase of wind force on the model. It was observed that the solid type windbreak is most effective in shielding the model from wind. Next to solid wall was the hedge type barrier in terms of effectiveness in shielding the model and the tree type barrier was found to be the least effective of all. This finding is interesting since it has been long regarded that trees are effective in shielding houses from wind. A comparative representation of the maximum wind force developed at 25m/sec wind in the presence of different kind of windbreaks is shown in Figure 2.44. It was seen that a tree barrier can reduce the wind thrust by about 39%, the hedge type barrier can reduce it by about 54% and the solid wall type barrier was effective in reducing the thrust by 86%. This phenomenon may be explained by the fact that in the case of solid wall (see Figure 2.45), the wind flow is fully deflected upward and the flow passes over the model, creating a static zone beneath. In such a situation, only a small amount of force is produced on the model, due probably to local turbulence.

The behaviour of the hedge type barrier is similar to that of the solid wall. However, a hedge is not fully opaque to wind. The presence of small openings causes a portion of the flow to pass through the hedge; this flow is able to hit the house directly, producing some thrust.

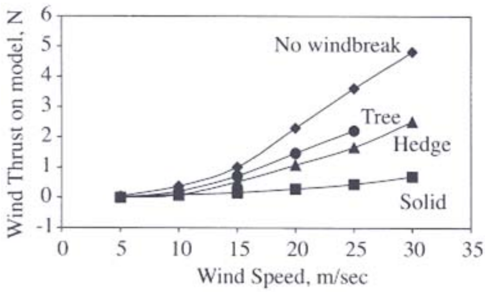


Figure 2.43: Wind Force on Chapra Model in Presence of Windbreaks (windows closed)

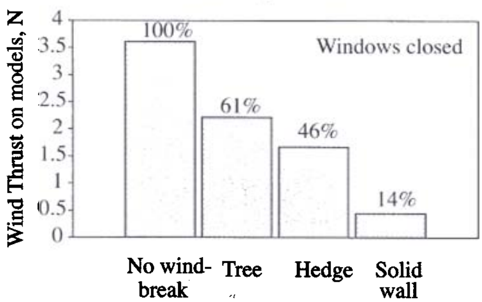


Figure 2.44: Comparison of Maximum Wind Forces Produced on the Chapra Model in Presence of Different Windbreaks

The least effectiveness of tree barrier among the three types studied can be attributed to the fact that in the case of trees, wind jetting occurs beneath the trees. Due to the presence of large openings beneath the trees, wind can easily pass through and hit the model, which reduces their effectiveness. This result reveals that large trees like mango or jackfruit trees may be less effective than they were thought to be, unless they are accompanied by dense bushes that would be able to prevent wind jetting beneath the trees.

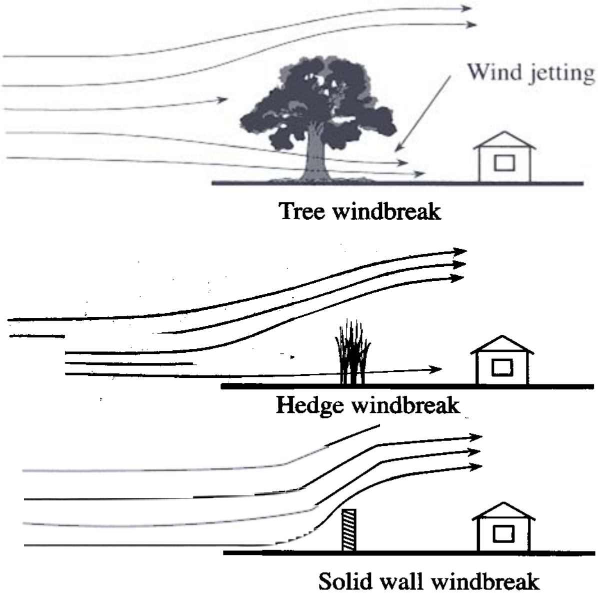


Figure 2.45: Wind Flow Patterns for Different Types of Wind Breaks

2.5.7 Summary Study in the Wind Tunnel

Of the three types of model studied, the Chou-chala appeared to be the safest type. Thrust was maximum on the Do-chala type. Study of the effect of presence of openings reveals that at low wind speed a closed condition produces less thrust than open conditions, but at high wind speed, the conditions of opening do not have much influence on the maximum thrust. It was found that the presence of a verandah increases the vulnerability of the Do-chala and Chou-chala type, while in the case of the Chapra, the presence of a verandah actually lowered the thrust. In studying the effect of different types of windbreaks it was found that due to the occurrence of wind jetting, trees may not be as effective as they were thought to be. Hedges were found to be relatively more effective if they can be made to sustain the wind. Of all the windbreaks, solid wall type was found to be the most effective in shielding the model.

2.6 Selection of Post-Disaster Shelter

Bangladesh is faced with the perennial problem of floods and cyclones occurring every year. The existing housing for the majority of the population, particularly in rural areas, is very weak and incapable of resisting the extreme loads generated during these natural calamities. The large-scale destruction of housing during these natural events demands major efforts for providing emergency shelter to the affected people. Assistance in providing post-disaster shelter is, therefore, one of the major concerns of the government. A large number of Government Agencies and Non-Governmental Organizations (NGOs) of Bangladesh are involved in providing post-disaster assistance which includes materials for temporary shelters.

Agencies involved in post-disaster relief operation would naturally like to utilise their limited resources in the best possible way. The various shelter options and technologies available in Bangladesh differ in cost, durability as well as quality of services provided by them. Bangladesh University of Engineering and Technology (BUET) was entrusted by the Aid Management Office of the British High Commission, Dhaka, to develop guidelines for selecting an appropriate shelter from among a wide range of alternatives. BUET organised a series of workshops entitled "Post-Disaster Shelter Options" in 1994-1995, where the participants came from various national and international organizations involved in post-disaster management across the country, as well as from academia. During the course of the workshops, various facts, figures and experiences concerning shelter options following a disaster were collected. BUET developed a methodology for evaluating the different shelter options, where a Value for Money (VfM) index was calculated for all the options in a rational and simple manner. During the workshop deliberations, BUET showed the use of the method with data collected from the participants. The objective of this section is to present this methodology, which can be used by organisations involved in providing shelter to poor communities in the aftermath of natural disasters. Numerical results are also presented to demonstrate the application of the method.

Various shelter types have been used in post-disaster emergency situations in Bangladesh. Some of them were meant to provide basic emergency short-term shelter and are weak in terms of strength and stability. Yet they were considered as viable choices and have been used extensively because of their low cost, easy handling and ease of fabrication. Other shelter options are stronger and more durable; however, they naturally require more investment. It is necessary to weigh the relative advantages and cost of different options available for making the appropriate choice with available resources.

During the course of the workshops, thirteen shelter options (S1 through S13), presented below, were identified as choices which could be provided after a disaster.

2.6.1 Plastic Sheet-Bamboo (Shelter Option S1)

In this structure, the roof and side-walls are made of plastic sheeting tied to a bamboo framework with wire or rope (Figure 2.46). Bamboo poles are used as column supports. This shelter has the advantages of being the cheapest shelter, easy to handle (light-weight, easy storage and transportation), with salinity resistance and flexible applications. Superior quality plastic sheeting can subsequently be used to waterproof the roof of a thatch-bamboo house. Disadvantages include transparency (lack of privacy), susceptibility to fire hazard, heat increase in hot weather, inadequate protection against further storms due to lack of strength and short life (damage due to ultraviolet sunlight). Plastic sheets are produced locally; however, superior plastic sheets may have to be imported.

2.6.2 Canvas Tarpaulin (Shelter Option S2)

Only jute/cotton canvas tarpaulins are delivered. Beneficiaries scavenge bamboo poles or tree branches to make a frame to which the canvas is tied with wire or rope. In comparison to plastic sheeting, tarpaulins are more expensive, more comfortable and provide privacy. Although they are about twice as heavy as plastic sheeting, they still have the advantage of easy handling (storage and transportation). Canvas tarpaulins can be numbered and tracked, which is preferable from a management point of view. Canvas is produced locally by a small number of industries that may not be able to meet the large demand in the event of a major disaster. Tarpaulins are not available in the sub-national markets. Disadvantages include: incompleteness, requiring additional framework, which causes deforestation at user localities; high fire risk; vulnerability to insects and rodents during storage and use; inadequate strength against strong storms; short life, due to ultraviolet sunlight causing deterioration if the tarpaulins are continuously wet; and susceptibility to tearing.

Figure 2.46: Plastic Sheet-Bamboo Shelter

2.6.3 Permatent Shelter (Shelter Option S3)

The Permatent is a complete one family emergency shelter and only needs simple digging tools for its erection. It is manufactured in the UK, but there are plans to make it also in Bangladesh. Each Permatent unit consists of three steel trapezoidal profiled sheets, 1.1 m wide and 0.55 mm thick, which are crimp-curved and when interlocked together form a free standing shell type structure (Figure 2.47). The steel is hot-dip galvanised, primed and has a durable polyester coating applied to both surfaces. All steel sheets are marked for tracking convenience. The two endwalls are made of polythene backed jute canvas, one has a window and the other has a door. The floor space is about 14 square metres.

The Permatent has a projected minimum life of about 20 years and can be put to multiple use as temporary shelters for 15 to 20 times. Advantages of such a system include completeness of structure that is easy to erect, high strength capable of resisting strong winds, maintenance free, fire resistant and easily repairable, polyester coating reflecting solar heat keeping interior cooler than other similar forms of roofing, multiple use if retrieved, and re-use later as a roofing unit for low-cost housing. Demerits are its high initial cost disallowing free distribution, large sheets being somewhat awkward to handle and transport, heat gain in hot weather, and problems of socio-cultural acceptability of this new structural form.

2.7.4 Canvas Tents (Shelter Option S4)

Canvas tents are distributed complete with poles, ropes, etc. They are more acceptable to the people as they are commonly used by settlement officers, scouts or armed forces. They are complete shelter options. The relative merits and demerits of use of canvas material have been discussed earlier. If imported, their price may be much higher compared to locally produced tents. This type of shelter option is generally suitable for short term use.

Figure 2.47: Permatent Shelter

2.6.5 C.I. Sheet-Bamboo (Shelter Option S5)

In this option, a complete package of materials is supplied for the erection of a low-cost house with corrugated iron (C.I.) sheet roof with wooden or bamboo roof support and bamboo poles, and with bamboo mat side walls. Figure 2.48 shows a photograph of C.I. sheet-bamboo shelter. Advantages include ability to store and transport easily, availability in local market, strength and durability, locally repairable, familiarity to people, fire resistantance and re-usability. When new, the galvanising reflects the sun's heat, which, however, begins to rust after a few months. Disadvantages include: requirement of additional tools for erection; danger of C.I. sheets fixed insecurely being flown away during storms; susceptibility to damage in saline conditions; and heat gain in hot weather. C.I. sheets are not normally marked by numbers and cannot be tracked. The critical element in such housing would be to provide proper securing mechanism of the C.I. sheet with the structural framework.

Figure 2.48: CI Sheet-Bamboo Shelter

2.6.6 Thatch Bamboo (Shelter Option S6)

This shelter option consists of a thatch roof supported on a bamboo frame and bamboo poles with bamboo mat walls. Fig. 2.49 shows a photograph of thatch-bamboo shelter. The thatch roof should preferably contain polythene sheet between layers of thatch for waterproofing. This type of house would be very inexpensive, but would have the disadvantage of being relatively weak against strong winds and having a shorter life. The materials used are also vulnerable to fire.

2.6.7 C.I. Sheet Wood-Bamboo-RC/PC Columns (Shelter Option S7)

This shelter option would be similar to option S5 with the main difference of having reinforced concrete (RC) or prestressed concrete (PC) columns in addition to bamboo poles (Figure 2.50). Naturally such a house would be much stronger and resistant to winds. The pillars and poles may be embedded below the ground level. The roof support system is wooden. A house of 3 metres by 5 metres may have 6 RC columns with footing in addition to bamboo posts and have bamboo wall matting, wooden roof support and C.I. sheet roof. This option would naturally be more expensive, requiring longer erection time and skilled labour.

2.6.8 All PC Dryland Model (Shelter Option S8)

This shelter consists of a demountable prefabricated prestressed concrete house model (MARC, 1994) developed under a UNCHS-funded project by Multi-disciplinary Action Research Centre (MARC). The manufacturer claims it to be sufficiently strong against cyclonic storms with speed up to 230 kmph. This long-term shelter would naturally be an expensive option and require skilled labour.

Figure 2.49: Thatch-Bamboo Shelter

2.6.9 Plastic Sheet only (Shelter Option S9)

Under severe circumstances, only plastic or polythene sheets may be distributed. The users gather bamboos, poles and branches to make a framework to which the sheet is fixed with rope or wire, if available. Relative merits and demerits of plastic sheeting have already been discussed. A major disadvantage of not providing framework material is that deforestation may occur locally.

Figure 2.50: C.I. Sheet and Bamboo House with RC Columns at the Corners

2.6.10 C.I. Sheet only (Shelter Option S10)

C.I. sheets may be distributed alone without supplying materials for the framework of the shelter. The beneficiaries may prop the C.I. sheets on the ground leaning together to form a tent-like structure. Alternatively, they may collect bamboo or branches to make a framework and fix C.I. sheets as the roof using wire, ropes and nails. They themselves have to provide materials such as bamboo mats for the side walls. The merits and demerits of using C.I. sheet have been discussed earlier. Figure 2.51 shows houses made entirely of C.I. sheet.

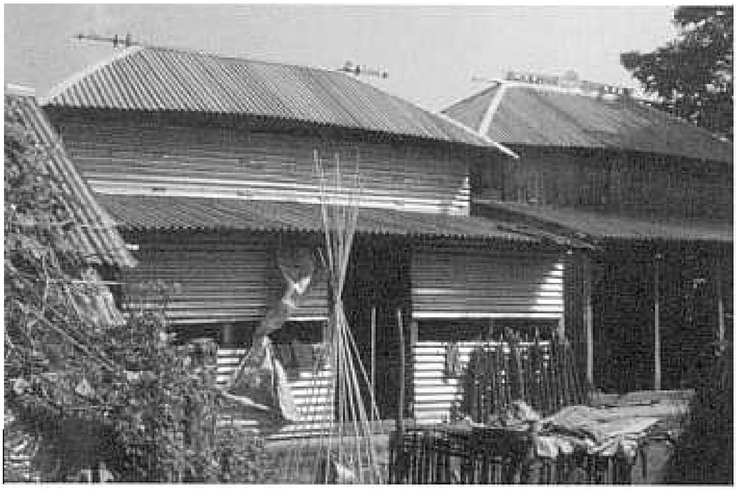


Figure 2 .51: C.I Sheet House

2.6.11 C.I. Sheet-Steel Truss (Shelter Option S11)

This shelter is similar to option S7 with the difference of having a stronger and more durable roof support system consisting of steel truss instead of having a wooden roof support system.

2.6.12 LGED Model 10A (Shelter Option S12)

This is a long-lasting shelter option developed by the Local Government Engineering Division (LGED) of Bangladesh. The house consists of RC pillars, ferro-cement slabs for roofing on RC frame support system and bamboo mat walls (Figure 2.52). This would require skilled labour for erection.

2.6.13 LGED Model 10E (Shelter Option S13)

Another shelter option has been developed by the LGED and consists of steel angles as the support system for both the columns and the roof. The walls are bamboo matting and C.I. sheet is used as roofing.

2.6.14 Governing Factors

In developing a methodology for comparison among different shelter options, the different parameters are first identified. Factors to be considered in evaluating the Value for Money (VfM) indicator for each shelter option include the quality factors and the cost factor, described below.

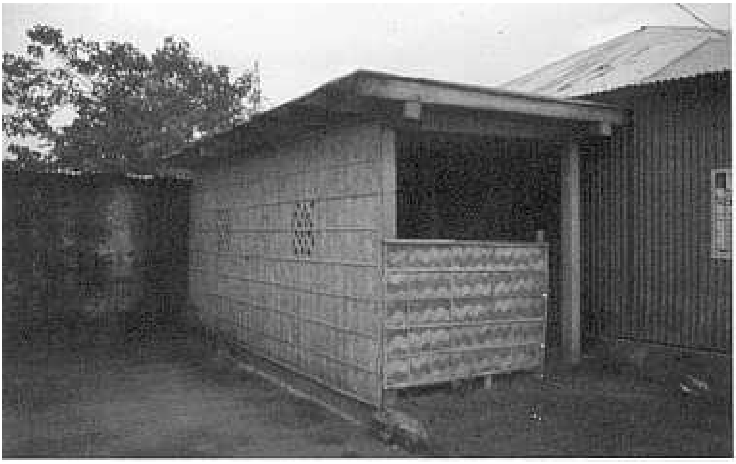


Figure2.52: LGED Model House

2.6.15 Quality Factor

The quality or benefit factors are the factors which the donor organisation, providing emergency shelters to disaster affected people is looking for when deciding to provide the shelter. Eleven quality factors for assessing emergency shelter options are found to be important:

1. Mobilisation time (includes procurement time plus transport time to disaster site)
2. Ease of storage
3. Possibility of re-use and multiple-use
4. Time and ease of erection (whether tools or special skill are required)
5. Structural strength and stability (resistance to high winds; normally emergency shelters are stored in a place safe from surges or flood after the hazard has passed)
6. Health and safety of occupants (environmental protection, fire resistance, etc.)
7. Social acceptability (privacy, comfort, etc.)
8. Completeness of shelter
9. Durability (life of shelter)
10. Ease of administration (to prevent misuse and misappropriation of funds and resources)
11. Environmental impact

2.6.16 Cost Factor

The cost factor is the cost per square foot of usable space inside the shelter, taking into consideration its use for one disaster cycle only. This includes the following costs:

(i) Material cost
(ii) Labour cost

(iii) Transport cost
(iv) Administration cost
(v) Storage cost

All available sources of information should be investigated to get a realistic estimate of the cost which for the same shelter option is likely to vary considerably. It is quite obvious that transport costs, storage, etc. would be dependent on factors such as location, locality, nature of disaster, etc.

2.6.17 Methodology for Evaluating Options

This is a new methodology which integrates all pertinent factors into a single Value for Money (VfM) index. It is based on a methodology developed for overall technology assessment by Sharif and Sundararajan (1983). Their method, however, appears to be too rigorous and intricate for general use by disaster managers. The method suggested here is more simplified, yet rationally takes into account the interplay of all factors.

The different steps to be followed in the proposed methodology are described below. Numerical data received from the workshop participants, including two reports by MARC (1994) and EDM (1994), are used in the demonstration of the method. Ranking of the different shelter options based on Value for Money is then presented. It should be noted that this ranking cannot be used directly, since limited data was available.

2.6.18 Weightage of Quality Factors

The weightage, in other words the relative importance index, for the different quality factors, needs to be established. The weightage reflects how important these factors are in meeting the objectives of the post-disaster shelter from the donor's point of view. The following procedure is recommended for the determination of weightage. First determine which factor is of the least importance. Put a score of 1 (one) for the least important factor. Now compare the other factors with this factor. If the other factor is equally important, put 1 for that factor also. If not, put a score to the other factor on a scale of 3 to 9 following the general guidelines given in Table 2.5.

The weightage (Wi) of the eleven quality factors is taken as the mean value of the data received from the workshop participants, as shown in Table 2.6. The maximum and minimum values received are also presented to give an indication of variation of participant response.

Table 2.5: Guidelines for Determining Weightage (Scale of 1 to 9)

Weight-age	Definition	Explanation
1	Equal Importance	Importance of this factor and weakest factor is similar
3	Weak Dominance	Experience or judgement slightly favours the factor over the weakest one
5	Strong Dominance	Experience or judgement strongly favours the factor over the weakest one
7	Demonstrated Dominance	Dominance of the factor over the weakest factor has been obviously seen from past experience
9	Absolute Dominance	Evidence favouring the factor over weakest factor has been affirmed to highest possible level

(Scores of 2,4,6,8 may by given if deemed appropriate)

2.6.19 Relative Quality Scoring

Each of the shelter options is now given a relative Quality Score (Qi) in a scale of 1 through 9, when considering each of the eleven quality factors. Each row of Table 2.7 presents a relative scoring of the various shelter options when considering a particular quality factor. For the eleven quality factors, there are eleven sets of guidelines for scoring, listed in Table 2.8. Table 2.7 represents the average value of scores that were received from the workshop participants. The variation is not presented here, but it needs to be noted that significant variation can exist due to lack of knowledge about the different shelter options. The response received had also large variations for some cases and it is considered best to use the average value.

Table 2.6: Weightage for the Quality Factors

Q.F. No	Quality Factor (Q.F.)	Mean (Wi)	Maximum	Minimum
1	Mobilisation time	8.5	9.0	7.0
2	Ease of storage	6.5	7.0	5.0
3	Reuse/multiuse	6.5	7.0	5.0
4	Erection	7.3	8.0	7.0
5	Strength/stability	5.8	7.0	5.0
6	Health/safety	4.8	9.0	2.0
7	Social acceptability	4.3	8.0	1.0
8	Completeness	6.3	7.0	5.0
9	Durability	6.0	7.0	5.0
10	Administration ease	7.3	8.0	7.0
11	Environmental impact	5.5	8.0	3.0

2.6.20 Value for Money (VfM)

The proposed methodology is based on the rational determination of a Value for Money (VfM) index for each shelter option. The "Value" is a measure of the overall quality of the option, while the "Money" stands for its cost. Based on available resources and VfM index, the donor can choose the appropriate shelter.

The "Value" of a particular shelter option is a complex combination of the different quality factors, some of which may be partially overlapping. A simple and rational method to obtain the Value would be:

$$\text{Total Value} = \sum_{i=1}^{11} W_i Q_i$$

The "Value" for a particular shelter option is thus determined by multiplying the different quality scores by their corresponding weightages (Table 2.6) and adding them up, as shown in Table 2.7. This Table (bottom row) also includes the total cost per square foot of usable area for each shelter option. The "Value for Money" index (VfM) is obtained by dividing the "Value" by the "Cost".

$$\text{VfM} = \frac{\text{Total Value}}{\text{Total Cost per sq.ft. of usable space}}$$

2.6.21 Ranking of Shelter Options

Table 2.9 gives the VfM index and relative ranking of all shelter options, based on data in Table 2.7. The option with the highest VfM score will naturally be the best choice to the post-disaster shelter donor agency.

It should be noted that the VfM value for shelters may change for different disasters, regions, time periods, market situations, etc. The relative ranking of various shelter options in Table 2.9 are based on the assumption that the materials used for making the shelters are not re-used.

If it is possible to retrieve shelter materials or recover its cost from the disaster affected people at the end of the crisis, for shelters with durable components, the possibility of re-use in future post-disaster situations becomes possible. Re-use is considered for some shelter options, as described in Table 2.10. Due to re-use, the cost factor decreases (compare with Table 2.9) and the VfM index increases. Table 2.10 presents the new ranking for this case. Whether the shelter materials are at all retrievable from the poor people needs to be verified in the field before considering re-use.

Table 2.7: Relative Quality Scoring of Shelter Options with Respect to Selected Quality Factors (Average Value)

QUALITY FACTORS	Wi	Shelter Options												
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
Mobilisation time	8.5	5.3	7.3	4.3	6.3	5.0	4.3	4.0	2.3	9.0	7.0	5.7	2.0	3.3
Ease of storage	6.5	7.0	6.7	4.7	6.7	6.3	4.7	4.7	2.7	9.0	7.3	6.0	3.3	3.3
Reuse/multiuse	6.5	6.3	6.0	4.0	4.7	7.0	4.3	6.7	3.7	5.0	8.0	7.7	4.3	7.7
Erection	7.3	8.0	7.0	7.7	7.7	6.0	5.7	4.3	1.0	6.3	5.7	7.0	2.3	3.0
Strength/stability	5.8	2.0	3.0	7.0	4.3	5.3	5.0	7.0	8.7	1.7	3.7	7.0	7.0	8.3
Health/safety	5.8	2.7	3.3	6.0	4.3	5.5	4.0	6.3	8.0	2.3	3.0	7.0	7.7	8.3
Social acceptability	4.3	6.5	4.7	4.7	5.0	7.0	5.0	7.7	7.0	2.3	5.7	8.3	6.7	7.7
Completeness	6.3	7.0	5.0	7.0	7.3	6.3	6.7	6.7	6.7	5.0	4.7	4.7	6.0	6.7
Durability	6.0	2.3	4.0	7.3	4.0	5.7	4.0	7.3	9.0	2.3	6.0	7.3	7.7	8.0
Administration	7.3	5.7	7.0	6.0	7.3	5.0	5.3	5.0	2.7	8.0	6.7	6.3	2.7	3.7
Environmental impact	5.5	2.3	4.3	6.7	6.0	6.7	7.3	4.7	7.7	3.0	4.7	6.3	7.3	7.3
TOTAL VALUE SCORE		**357.3**	**342.7**	**413.5**	**411.5**	**412.0**	**355.4**	**398.1**	**353.7**	**310.7**	**404.3**	**437.6**	**321.4**	**408.2**
Cost, Taka/sqft (US$/sqft)		34 (0.75)	30 (0.66)	100 (2.22)	44 (0.98)	70 (1.56)	38 (0.84)	94 (2.09)	300 (6.66)	25 (0.56)	35 (0.78)	80 (0.78)	156 (3.47)	115 (2.56)

Table 2.[illegible]: Guidelines for Scoring Different Shelter Options with Respect to *Various Quality Factors*

	Weightage		
QUALITY FACTORS	**9**	**5**	**1**
Mobilisation time	< 1 day to mobilise	15 days	<45 days
Ease of storage	Easy	Sometimes reused	Never reused
Reuse/multiuse	Always reused	Average	Difficult
Erection	<1 day to erect	10 days	<30 days
Strength/stability	Stable under extreme hazards	Stable under normal conditions	Weak
Health/safety	Ensures health & safety under all situations	Ensures health & safely under normalconditions	Always unsafe for occupants
Social acceptability	Totally acceptable	Acceptable with reservations	Local people totally reject the option
Completeness	Shelter provided is complete	Requires some additional material by user	Requires maximam extra material by user
Durability	Shelter life> 20yrs	5 yrs	< 0.5 yrs
Administration	Perfectly manageable	Manager experiences some problems	Extreme management problems
Environmental impact	No impact on environment	Average adverse impact	High adverse impact on environment

Code	Shelter Option Value	Total	Cost (Tk/Sft.)	Value for Money (VfM)	Rank
S1	Plastic Sheet-Bamboo	357	34	10.5	4
S2	Canvas Tarpaulin	383	30	12.8	1
S3	Permatent	414	100	4.1	10
S4	Canvas Tents	412	44	9.4	5
S5	C.I. Sheet-Bamboo	412	70	5.9	7
S6	Thatch-Bamboo	355	38	9.3	6
S7	C.I. sheet-Wood -Bamboo-RC/PC columns	398	94	4.2	9
S8	All PC Dryland Model	354	300	1.2	13
S9	Plastic Sheet only	311	25	12.4	2
S10	C.I. Sheet only	404	35	11.5	3
S11	C.I. Sheet-Steel Truss	438	80	5.5	8
S12	LGED Model 10A (PC-FC)	321	156	2.1	12
S13	LGED Model 10E (C.I. sheet-steel angle)	408	115	3.5	11

Table 2.9: VfM Score and Ranking of Shelter Options (Not Considering Re-Use of Shelter Materials)

2.6.22 Discussion of Results

The data that forms the basis of the results presented here are drawn from the response of workshop participants and reports presented at the workshop (MARC, 1994; EDM, 1994). The outcome of this study cannot be directly applied as limited response was received from the participants of the workshop. More extensive data is required for obtaining reliable VfM values that can be used.

The Value for Money (VfM) considered here is the value for the donor or aid-giving agencies' money. The unit costs (Taka per sq.ft. of usable space) are considered for short term use for one cycle of disaster only, which is one year. Practical experience of NGOs and relief organizations working in Bangladesh indicate that most or all shelters are non-retrievable after distribution in a disaster. However, reuse and multi-use of shelter/shelter material by end users may still be considered an important shelter quality or attribute from the donor's point of view. The results are likely to be sensitive to changes in geographical location (with probable changes in transportation facilities and market facilities), type of disaster (flood or cyclone), etc.

Code	Shelter Option	Total Value	Possibility of Re-use	Cost (Tk/ Sft.)	VfM	Rank
S1	Plastic Sheet-Bamboo	357	No re-use likely	34	10.5	7
S2	Canvas Tarpaulin	383	Second use of one third inputs	25	15.3	2
S3	Permatent	414	Four re-use of four fifth inputs	36	11.5	4
S4	Canvas Tents	412	Second use of one third input	36.5	11.3	5
S5	C.I. Sheet-Bamboo	412	Two re-use of half inputs	47	8.8	9
S6	Thatch-Bamboo	355	No re-use likely	38	9.3	8
S7	C.I. Sheet-Wood-Bamboo-RC/PC columns	398	Two re-use of half inputs	70	5.7	10
S8	All PC Dryland Model	354	No re-use, likely to be permanent	300	1.2	13
S9	Plastic Sheet only	311	No re-use likely	25	12.4	3
S10	C.I. Sheet only	404	Two re-use of	23	17.6	1
S11	C.I. Sheet-Steel Truss	438	The re-use of three-fourth inputs	40	11	6
S12	LGED Model 10A(PC-FC)	321	No re-use, likely to be permanent	156	2.1	12
S13	LGED Model 10E (C.I. Sheet-Steel Angle)	408	Two re use of three-fourth inputs	86.6	47	11

Table 2.10: VfM Score and Ranking of Shelter Options (Considering Re-Use of Shelter Materials)

Both the weightage of quality factors (Table 2.6) and relative quality scoring of shelter options against each of these factors (Table 2.7) were obtained as a mean of scores provided by the workshop participants. Their response showed a large difference in perception among different donor agencies with regard to some of the factors: Health/Safety, Social Acceptability, Completeness and Environmental Impact. Regarding the other quality factors there is great similarity in view regarding their importance. If the sample size was large, statistical measures such as standard deviation and confidence levels would provide a valuable guide to the reliability of the scores obtained. As the sample size was very small such statistical analysis would not be of significance and hence was not carried out. A practically acceptable result can only be obtained after statistically evaluating responses received from a large group of participants.

2.6.23 Value for Money Index

Relief and rehabilitation programs for disaster affected communities, following floods and cyclones, have a regular occurrence in Bangladesh. The donor or aid giving agency, in the absence of an accepted analysis procedure, is often faced with the difficult problem of selecting a particular shelter from among a wide variety of shelter options available. A simple methodology has been proposed here for the rational determination of a Value for Money (VfM) index for each shelter option. Evaluation of VfM is done from the relief manager or donor's point of view, keeping cost and quality of the shelter option as separate factors. The donors or disaster managers can use this index to judiciously select the shelter. The cost, hence the VfM index, for the same option may vary depending on factors such as geographical location, local market conditions, type of disaster, etc. The cost corresponds to use of shelters for short term (one year) only. If a particular shelter can be retrieved and re-used in future needs, the cost would be reduced accordingly. This, however, needs to be verified in practice. The purpose of presenting numerical results is to give an illustration of how to apply this methodology and to present a rough representation of whatever limited data that was received. It is recommended that in practice extensive data be collected in order to obtain a reliable assessment of the VfM index for the shelter options.

2.7 Improving Rural Housing In Bangladesh

The social, geographical and climatic factors which make Bangladesh's housing stock especially vulnerable to natural hazards are well-known. Those factors bear disproportionately on the homes of the poor and a major re-evaluation is needed at both Government and NGO levels to develop an overall strategy for improvements of rural housing.

This section deals specifically with issues pertaining to the improvement of kutcha housing (that is, houses made from bamboo, thatch and mud in which most of the population lives).

2.7.1 Population Increase

At more than 800 persons/km^2, Bangladesh's population density is among the highest in the world. Between the Census of 1991 and 1997, the country's population increased by almost 11 million, according to one estimate (BBS, 1991). That rate of increase by itself requires construction of 2.2 million homes annually of which 84% (1.8m) will be in rural areas.

As the population increases, so people are increasingly forced to live in low-lying areas vulnerable to floods and cyclones. At present, there are no major changes expected in the socio-economic profile of the country in which 75% are employed in agriculture producing 40% of the Gross National Product. Therefore, this state of vulnerability may be expected to persist for the forseeable future (25 years).

2.7.2 Ratio of Kutcha to Pucca Construction

In 1960 it was estimated that 90% of houses in Bangladesh were rural and of kutcha construction (bamboo, thatch and mud). At that time the ratio represented 8.2 million dwellings. By 1993 the rural housing stock represented 83% of the country's total and 75% of those were of *kutcha* or sub-*kutcha* (temporary) construction. It might be noted that the rise in urban construction probably includes a significant quantity of temporary slum dwellings and could reflect a deterioration in overall housing stock.

Projecting those figures in association with the population increase shows that the actual number of *kutcha* and temporary housing constructions will continue to increase for some time, even though these construction types may decline as a percentage (Figure 2.53).

2.7.3 Forces of Nature

The tropical monsoon climate gives between 55 inches of rain in the central border area and 200 inches in the northeast, of which 80% falls between late May and early October. The rain is often accompanied by severe wind-storms.

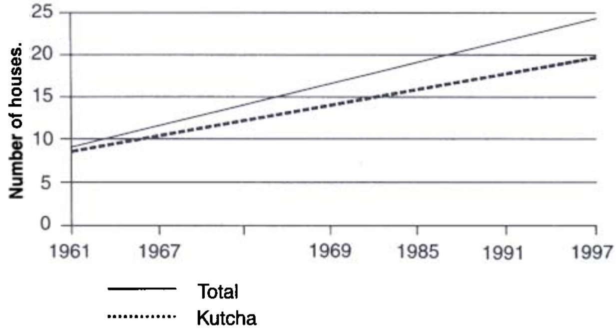


Figure 2.53: Projection of House Numbers

Figure 2.54 illustrates the effects on housing of some of the more severe natural events to have struck Bangladesh in recent years. It may be noted that, generally, more damage is caused by flooding than by wind. Flooding can occur twice during a year. Winds (cyclones and tornadoes) may cause very intense damage over their relatively narrow paths, but the major devastation in such cases results from the associated storm surges which can beup to 10 metres in height, evident from the 1991 cyclone.

To put these figures in context, the 1970 cyclone killed 300,000 and the 1974 floods affected up to 36 million people over an area of 87,000 square kilometres.

As well as the physical destruction of houses, flooding saturates the ground, reducing foundation stability, erodes river banks and redeposits silt and sand, affecting agriculture and reconstruction activities. Prolonged periods of flooding may thus affect *pucca* buildings as badly as *kutcha* ones.

Other natural hazards which affect Bangladesh, although not so significantly as flood and wind, include:

- Earthquakes: potentially serious, indicated in several recent tremors;
- Fire, especially in densely packed urban areas;
- Hail stones: golf-ball sized hail stones have been known to cause severe damage.

In the face of such a range of hazards, it must be accepted that it will be impossible to make a house of natural materials that can completely withstand all these.

2.7.4 Regional Vulnerabilities

Different areas are subject to differing intensities of hazards. This means that there is not one ideal solution to improving *kutcha* housing that can be applied in all places.

However, it may be possible to transfer technologies from one place to other suitable locations. For example, the steeply curved thatched roofs used in high rainfall areas are very strong in relation to vertical loads and could be encouraged elsewhere.

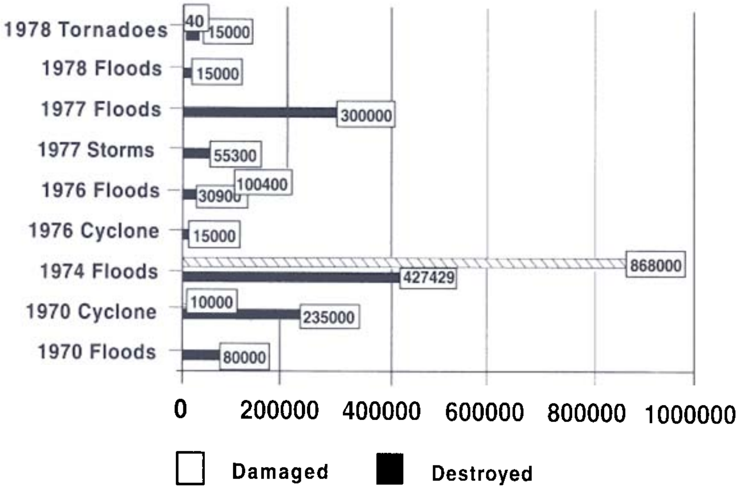


Figure 2.54: Houses Damaged or Destroyed by Natural Events, 1970-78

Four broad classifications of hazard can be identified. These classifications may, in time, be subject to clarification or refinement:

Subject to heavy rainfall with seasonal ground run-off;
2. Heavy rain with rising water and flash floods;
3. Heavy rain, flash floods, cyclones, tornadoes and "Nor'westers;
4. Heavy rain, floods, cyclones, tornadoes, "Nor'westers" and storm surge.

2.7.5 Economic Forces

Landlessness (75% of the rural population are functionally landless) and poverty force many people to migrate in search of income; the result is often movement to lower, more vulnerable ground in the *chars* and shifting deltaic areas. The existing distribution of power, income and assets is a major component of that vulnerability, reinforcing the benefits of the power system for those already in control. Major changes to the processes that create vulnerability need to be addressed (Blaikie et al., 1994).

Any building programme would have additional benefits in creating local employment and demand for locally produced materials. The increased confidence of rural communities as their housing stock improves should result in less mobility of families and create sociological continuity.

2.7.6 Disaster Preparedness Provisions

In areas most affected by extremes of climate, the creation of additional pucca housing can be seen as provision of communal safe havens. In such places, improved kutcha housing may have only limited benefit. Perhaps the "improvement" (say, a steel post) may be all that remains after the disaster. This could prove lifesaving if designed as an anchorage point or it might serve to identify the house location after the flood.

An important flood mitigation measure for kutcha housing is to raise the structure on a mound (*killa*) or stilts. Roads could be widened to provide stronger embankments and raised areas for the construction of houses. This would be more cost effective than constructing many individual killas, and the raised areas created could more easily be stabilised and protected by shelter belts of bamboos and trees. Such vegetation would also provide sustainable supplies of building materials.

2.7.7 Appropriateness of Improvements

Any suggestions for improvements to kutcha housing must take into account the appropriateness of the materials and respect for the local vernacular building types. Factors which influence the appropriateness of the material include:

1. Affordability/cost
2. Practicality of use
3. Availability
4. Transportability/location
5. National/international and donor culture

Respect for the cultural aspects of building needs to recognise:

1. Location
2. People and their experiences
3. Traditional materials and methods
4. Sociological aspects
5. Historical factors
6. Differences between rural and village/city dwellings.

2.7.8 The Emergency Period

Analysis of data available after the 1970 cyclone/surge wave showed that 83% of post-disaster shelter reconstruction were provided from within the affected populations. Outside assistance from the Government and NGOs accounted for only 17% of the new/repaired dwelling provision.

Within 2 days of the cyclone, people were rebuilding their homes. However, the emergency aid system was only just getting into action, hampered as it was by the damage to transport and communications networks.

It is inappropriate to try to introduce housing improvements in this emergency recovery period. Studies show that the ability to regenerate income is more a priority than shelter. Improved building methods take time to introduce and few can spare that time, even if the aid system has access. Improvements must be considered later. Unfortunately, by the time it is appropriate to consider building improvements, most agencies will have expended their housing budgets and have no reserve for improving what they have already done. Thus the status quo remains.

2.7.9 Dissemination of Knowledge

Dissemination of information on improved building methods must take place at three basic levels:

Between multi-disciplinary groups and international agencies;
2. Between key players within Bangladesh; and
3. Within rural communities.

Given that 75% of rural workers are functionally landless, that adult literacy is 35% or less of the population, that 8 out of 10 live below the poverty level and that 45% of the population is under 15 years of age, the keys to developing building for safety programmes will include:

1. Training of educators;
2. Development of appropriate methods; and
3. Practical (financial) support for programmes.

The last point above is important. Although improved building brings tangible results, lack of finance will often be an inhibiting factor and, for most rural families, income generation and improved health are generally higher prorities (Blaikie et al., 1994; Hodgson and Whaites, 1993). It is not practical to enforce a recommendation or legislation that casuses home-owners to spend an additional 5% on their homes, even if it were clearly for their betterment and safety. However, there is equally little chance of meaningful improvement without some form of government supplement and corresponding monitoring of the policy.

The following examples illustrate some of the problems encountered with technical transfer programmes in Bangladesh.

Example 1: Polythene sheet
Oxfam's experience and research during the 1970s showed that ultra-violet light degrades clear polythene into a brittle, non-waterproof material. The sheeting, when used for roofing, also causes increases in internal condensation with potential health risks. Nonetheless, there has been a limited transfer of this technology, originally used for emergency shelters, with local families copying the "sandwich" technique in their own, non aid-provided homes (Figure 2.55).

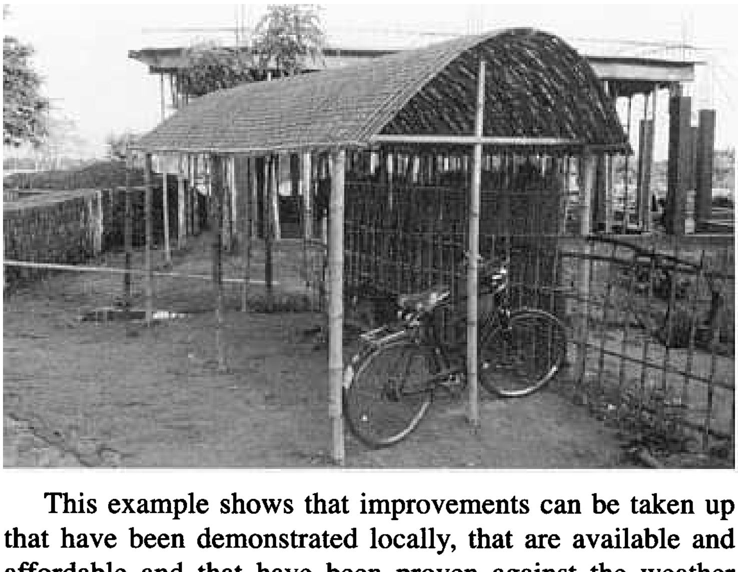


Figure 2.55: Polythene Sheet Roofing

This example shows that improvements can be taken up that have been demonstrated locally, that are available and affordable and that have been proven against the weather elements. However, people will usually wait to see how the new material performs in comparison with their existing structure before deciding to use it themselves. In other words, any building development must be tested in many places to ensure rapid acceptance and hence ready availability of the materials.

Such demonstration buildings need to be placed in accessible village locations to ensure maximum exposure to the population and to remove any psychological barriers that might be created by an isolated scientific test. Follow-up studies will need to ensure that good ideas are not lost in cases where poor buildings may be overwhelmed by disaster; there will be a tendency for onlookers to tar the whole structure with the same brush - "all useless".

Example 2: Protecting looms

Many home-made wooden looms, used in cottage industries, have their feet resting on brick or stone (Figure 2.56). Experience shows that this reduces the risk of rot and termite attack and the precaution is used widely throughout Bangladesh. Strangely, the adoption of this technology in buildings is a leap of transfer that is not often made naturally. Interestingly, one of the innovations proposed by participants at the H&H workshops in North Bengal was to do just this. It is not clear why the technique is not widely used.

Figure 2.56: A Hand Loom Cottage Industry

Example 3: Raised grain stores

Grain stores are commonly raised above ground level and strengthened with cross-bracings (Figure 2.57). These techniques are not often adopted by villagers when building their own dwellings. This raises several questions as to why this might be the case:

Figure 2.57: A Grain Store in Northern Bangladesh

1. Who introduced these techniques originally, and when?
2. Could it be that the original builders understood the principles and died before passing on their knowledge?
3. Is the low literacy rate a factor in the failure to transmit principles?
4. Do people place more value on their food stores (and contents) than they do on dwellings that have always been temporal in the face of ravages of nature?

Problems of technology transfer and retention are exacerbated by the frequency of natural disasters, the casualty rates and the low life expectancy (51 years).

Quite a while ago, the idea was put forward that the life of bamboo in contact with the ground could be prolonged by charring the ends and treatment with bitumen (or used motor-oil). This was proposed after discussions with rural house-builders. Work is still needed, twenty five years later, to demonstrate scientifically the extent to which this does improve bamboo life. The effects of different types of oil also remains to be tested. Clearly, there is still much research to be done.

2.7.10 Timescale for Change

In other fields of development, such as agriculture, medicine, literacy, healthcare and family planning, changes have occurred over periods of 25 to 30 years in small incremental stages. One major step in the development of community health has been the introduction of village-level para-medics to disseminate essential primary health information.

If a parallel can be drawn between building for safety and comunity health, then it would be logical to introduce "para-architects" who would be local people given basic training to disseminate simple construction improvements in their neighbourhoods. Such para-architects would be the basic agents for change over a 20 to 25 year period. The approach must aim for consistency and an appropriate scale of activity over that period.

In parallel with the field dissemination, scientific exploration of construction principles needs to be undertaken. Research into fast-growing varieties of bamboo and other materials appropriate to the soils of Bangladesh would also be beneficial.

2.7.11 Funding

All these suggestions, including a resource base and training centre, will require funding. However, the scale of the funding should be seen in the context of the damage caused to the national infrastructure and economy by natural disasters.

Currently, most of the resources applied to buildings are being put into pucca structures which acount for only 16% of the housing stock. While these can and do provide safe havens in times of disaster, the wide distribution of the population and their reluctance to leave their home until the last minute makes this role one of only marginal value.

As a simple example, if just 1% of the damage caused by the 1974 floods had been saved, then the cost of reconstruction would have been reduced by $5.79 million (equivalent to over $20m today). Since nearly a third of the damage was to domestic housing, improved building technologies could save the nation considerable sums. Better housing also protects property so the savings might be greater in practice.

External aid to Bangladesh amounts to 5% of the GNP (and totalled $1,386m in 1993). 95% of the country's development programmes are financed from abroad. The National debt stood at $16.6bn in 1994 (New Internationalist, 1997-8). It could be argued that a small percentage of these sums put into improvements to *kutcha* housing could improve the lives of the 84% of the population who live in them and might free up expenditure for other development activities.

2.7.12 Proposed Strategy

It is possible to introduce improved technologies into the annual house-building/maintenance cycle using indigenous materials and techniques and available funding.

The dwelling is a costly family asset. Repairs to *kutcha* buildings are needed frequently, but are cheaper than the initial cost of a pucca house. The main housebuilding season occurs after planting, so there is little surplus cash in the home. Income generation is a higher priority than shelter after a disaster, so house repairs are put off. Most people therefore cannot afford even simple improvements which might protect their main asset.

The costs of improvement amount to between 5% and 8% of the basic new house cost (Carter, 1997). A basic house can cost around Tk 2000 so the improved model will cost Tk 2160. Improvements are more cheaply included in new construction than in repair programmes and should be seen as offset by long-term benefits.

Appropriate improvements would include:

- Lower parts of posts charred and bitumenised;
- Wall and roof-frames cross-braced;
- Wire lashings at roof/wall/post junctions;
- Roof support frame strengthened;
- Roof strengthened;
- Lower parts of bamboo mat walls treated;
- Mud plinth stabilisation.

Possible sources for funds include:

- Government: within change of policy towards rural housing;
- NGOs: on-going programmes;
- Disaster relief funds: within rehabilitation programmes;
- House owners: own funds for new houses;
- Bank/co-op loans: Local banking and micro-credit facilities.

2.7.13 Proposed Alternative Housing Programme

New housing programmes should be designed as a mix of improved *kutcha* and a small proportion of *pucca* homes which act as safe havens. Rather than building 50 *pucca* homes, the same funds might provide 100 improved kutcha dwellings plus 10 pucca ones and improvements to ancillary structures, such as kitchens and tubewells, to create general improvements in environmental conditions within the community. This would benefit a much larger number of people, but could generate disputes as to who would get the pucca homes and what arrangements would be made for their use in emergencies.

Element	All pucca house 50 Pucca homes	Proposed alternative 100 kutcha, 10 Pucca+ ancillary structures
NHBRI model concrete house.	50 X Tk16,000 = 800,000	10 X 16,000 = 160,000
Improved *kutcha* houses.		100 X 2,160 = 216,000
Improve existing dwellings.	TOTAL, Tk.	600 X 200 = 120,000
Provide educational materials.		82,500
Employ workers 10 weeks@Tk 45/ day.		30 X 2,250 = 67,500
Leaving balance for : Community preparedness/flood markers/etc. Raising tubewells above flood level. Planting bamboo as windbreaks, etc. Investing in microcredit fund for building contingency .		30,000 20,000 24,000 70,000 10,000
	800,000	800,000

Table 2.11: Comparative Costs in Taka (Note that land costs are not included)

The total cost of such a project would be Tk 800,000. This illustrates how it is possible, within the cost of 50 pucca houses, to provide new improved homes for 110 families and to upgrade a further 600 homes. Thus, up to 14 times the number of families would benefit. The community could be involved in its own disaster preparedness and substantial employment could be generated. Clearly, other mixes of activities in the alternative proposal are possible and may be appropriate, depending on local circumstances.

The benefits could be spread even more widely by providing some of the funding on a credit basis. This could help to transfer ownership to the community and the revolving fund would be seen as a way of sustaining further improvements for others.

2.7.14: Need for Change

Since no major changes can be predicted in the national economy, and, hence, the ratio of *pucca*-to-*kutcha* housing might remain the same over the coming 25 years, it can be argued that current funding and energy being spent on pucca housing improvements is inappropriate in terms of rural/urban housing ratios.

If improvements to the rural housing stock amounting to 8% of the initial construction cost (an additional Tk 160 per house) could reduce disaster damage by 1%, then Tk 75 - 90 crore could be saved during major events.

Over 1.8 million new rural homes are needed each year just to cover the population increase; concerted action is needed now to ensure that these dwellings are safe and affordable. Past experience has mostly been of measures which have been too little, too late and not sufficiently scientifically founded. Housing must be raised as a national priority concern.

As an old African proverb says, "It's better to light a candle than to curse the darkness."