

## SOME ASPECTS TOWARDS DEVELOPMENT OF HAZARD-RESISTANT RURAL HOMES IN BANGLADESH

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### Introduction

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 follow 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 the rural poor houses undergo partial or total collapse as they have little or no lateral load resistance. This paper proposes some treatments and techniques for the improvement of rural house bases and shows the vulnerability of rural houses to failure due to cyclic moderate wind loading.

### 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.

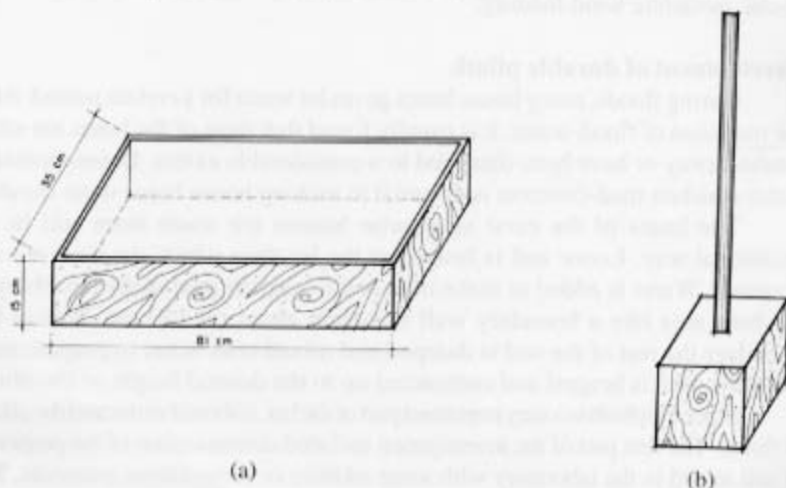
Since the plinth is a very important part of the hut, it should withstand the effects of flood. The first part of the investigation included determination of the properties of soil mixed in the laboratory with some additive or cementitious materials. This mixture has been termed here as *mud-concrete*. In this study, rice husk (RH), rice 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 (Fig. 1a) 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 (Fig. 1b) 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 1.

**Table 1 : Compressive strength of the mud-concrete**

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



**Figure 1 : Preparation of mud-concrete, (a) mould, (b) hammer**

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 have an idea about the effect of flood on the bases of the 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-fiber, straw, etc as cementing materials in the mud-concrete is yet to be investigated.

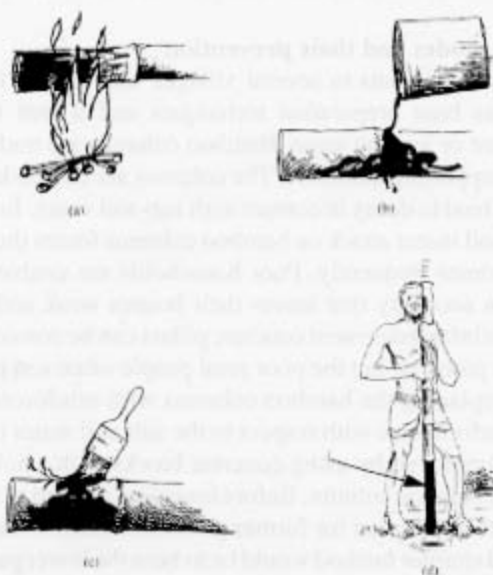
### Common failure modes and their prevention

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 the same. 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 of Bangladesh, 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 that leaves their houses weak and vulnerable to moderate wind. Reinforced cement concrete pillars can be considered as a great innovation for the problem; but the poor rural people often can not afford this.

Instead of replacing the bamboo columns with reinforced cement concrete pillars, its performance with respect to the sub-soil water or insect attack at its 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 with motor oil as shown in Fig. 2. Scorching dries the bamboo out completely, depletes internal cellulose from which insects derive nourishment, thus retarding insect attack. 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.

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 thus reduces the risk of lifting off of house roof. Use of jute ropes or special type of rope locally called as '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 roof frame can be tied down to the top wall beam and column as shown in Fig. 3.



**Figure 2 : Treatment of bamboo column, (a) scorching the bamboo, (b) covering with motor oil, (c) soaking in bitumen, (d) placing the column in position (after Chisholm, 1979)**

### **Properties of bamboo as a framing material**

Generally three types of bamboo are available in Bangladesh; they are locally called as mahal or talla, ora and barak. Among them barak is relatively thick-walled and widely used as column and beam which are locally named as khuti and paire/dhyanna (beam along long side/beam along 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 (Fig. 4a). For the tensile strength, the bamboo was split and a reduced section was prepared as shown in Fig. 4b. Compression test results of both types bamboo specimen and the tensile strength characteristics of bamboo are given in Tables 2, 3, and 4, respectively.

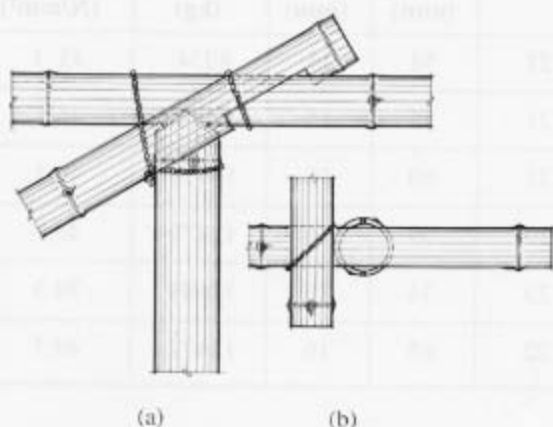


Figure 3 : Connection of house frames, (a) Three-dimensional view  
(b) Top plan of a joint

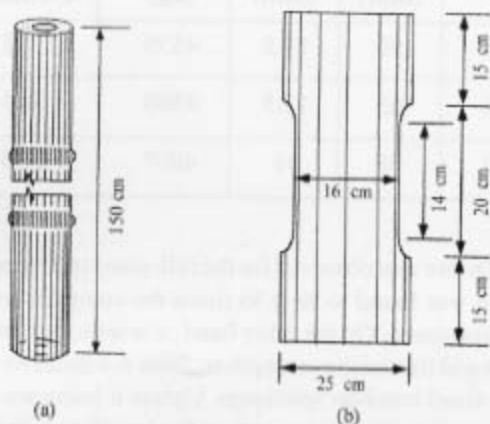


Figure 4 : Specimens prepared for testing, (a) Full-sized compression test specimen, (b) Tensile test specimen

**Table 2: Compression test results of bamboo (barak) specimen**

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

**Table 3: Compression test results of full size bamboo (barak)**

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

Buckling failure was observed for the full-sized specimen (Fig. 5) 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 the bamboo is very strong in tension and the tensile strength is about 4.4 times of the compressive strength of full-sized bamboo specimen. Unless it becomes weak due to the insect attack or by rotting, bamboo was found to be safe to withstand the stresses caused by the moderate wind-induced lateral load.

Table 4: Tensile test results of bamboo (barak) specimen

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

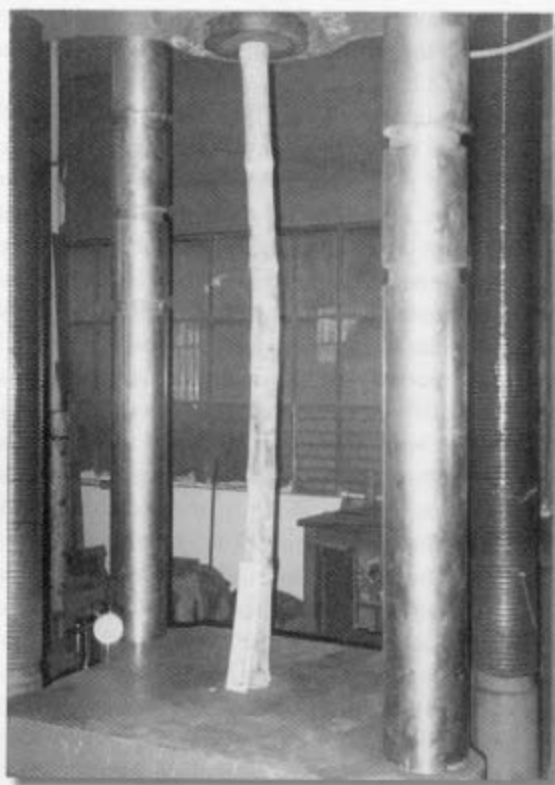


Figure 5 : Testing of full-sized bamboo specimen

### 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 needed insights into many fluid flow effects. It is required that the houses subjected to wind loads be sufficiently strong to perform adequately from a structural safety and serviceability view-point. 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 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 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 in the experiment.

Experimental set-up is shown in Fig. 6. Static load was applied uniformly to the frame of the house whose plan view is shown in Fig. 7 through a loading jack. The deflections of the house frame caused by static lateral loads were measured by a theodolite. During application of first cycle of loads, some small cracks were observed on the base soil adjacent to the bamboo columns and no repair works were made before the second cycle of loading. This has been done to simulate the phenomena of frequent storms of moderate speed that does not actually cause total collapse of the house. It is observed from Fig. 8 that the deflections during the second phase of loading are larger than that of 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.

Traditional rural housing is very light and fragile, and has the simplest form of a skeleton of bamboo framing formed by four corner poles framed by four struts in the horizontal plane at some height of 1.5-2 meter from the plinth level. Anwar (1996) has analyzed such a basic frame as shown in Fig. 9 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 6 : Test Set-up of full-scale rural house under lateral load

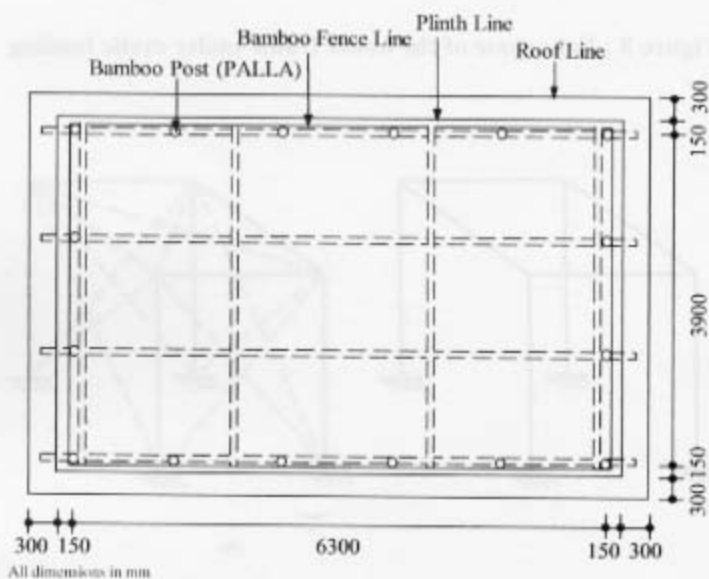


Figure 7 : Plan view of house under test

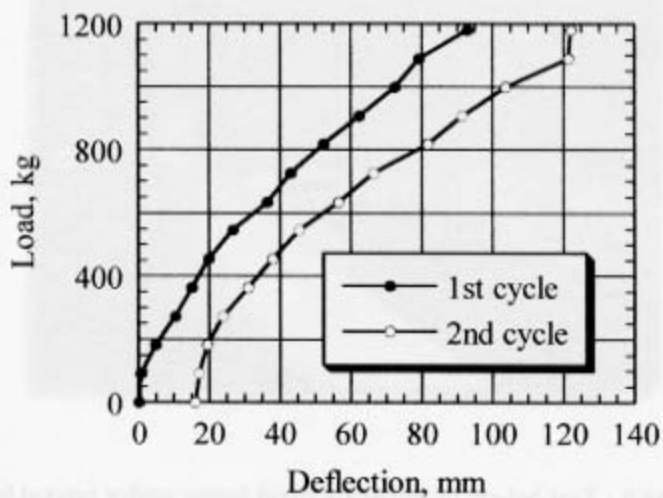


Figure 8 : Behaviour of the house frame under cyclic loading

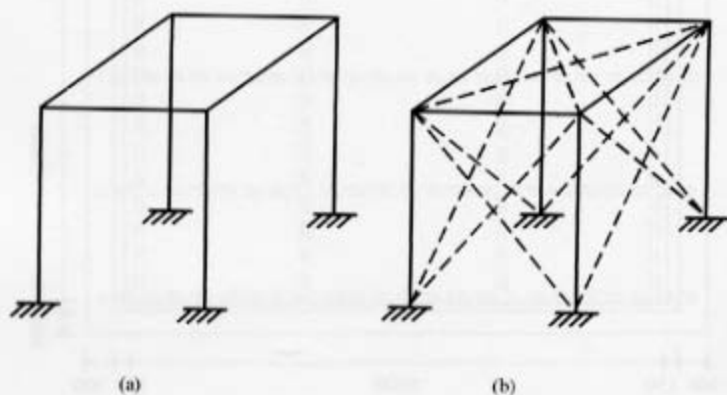


Figure 9 : Effect of wind braces, (a) basic frame,  
(b) basic frame with lateral braces.

## Conclusion

Experimental investigation has been carried out to understand the effects of flood on the plinth soil and to clarify the vulnerability of rural house to the cyclic wind loading. Based on the experimental results, the use of cement-soil mixture with 5% 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 rather using 5% by weight. Effect of different kinds of lateral bracing on the lateral load resistance potentiality of the full-scale house frame is still under investigation.

## References

- Anwar, A M M T (1999). Wind resistance of Non-engineered Housing. In *Implementing Hazard-Resistant Housing*, Proceedings of the First International Housing and Hazards Workshop to Explore Practical Building for Safety Solutions held in Dhaka, Bangladesh, 3-5 December 1996, edited by Hodgson, Seraj and Choudhury, pp. 23-27.
- Lewis, J & Chisholm, M P (1996). Cyclone-resistance Domestic Construction in Bangladesh., In *Implementing Hazard-Resistant Housing*, Proceedings of the First International Housing and Hazards Workshop to Explore Practical Building for Safety Solutions held in Dhaka, Bangladesh, 3-5 December 1996, edited by Hodgson, Seraj and Choudhury, pp. 29-38.
- Serajuddin, M (1980). Hand Compactors for Embankments, Proc. of Seminar on Appropriate Technology in Civil Engineering, Institute of Civil Engineers, London, England, pp.119-121.
- Simiu, E & Scanlan RH (1986). Wind Effects on Structures, 2nd Edition, John Wiley & Sons