MODELLING OF A BANGLADESHI RURAL HUT FOR WIND TUNNEL TEST

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Introduction

Developments in science and technology have made it possible to reduce natural disasters although it is difficult to reduce natural hazards. Bangladesh suffers from huge losses of both life and property almost every year due to natural hazards. Among these hazards, cyclone plays the key role. Most houses in cyclone-prone zones are non-engineered thatched construction which have virtually no lateral load resistance mechanism. They rarely can survive a cyclone of even moderate intensity. Total collapse of the structures causes loss of life as well as of properties. The objective of this paper is to select suitable lateral load resistance system, investigate the uplift mechanism of the root select proper location of door and windows, etc. for the rural hut through model tests of these huts in the wind-tunnel.

Housing practice in Bangladesh

The majority of houses in the wind hazard zones of Bangladesh are traditional self-built housing for the poorest class of people. These structures, mostly with thatched roofs, are not covered by any code. They exhibit little or no resistance to extreme winds. Collapse of this category is responsible for the majority of loss of life and injury during cyclonic storms. An improvement in their wind resistance potential will significantly contribute to minimising loss of life and property.

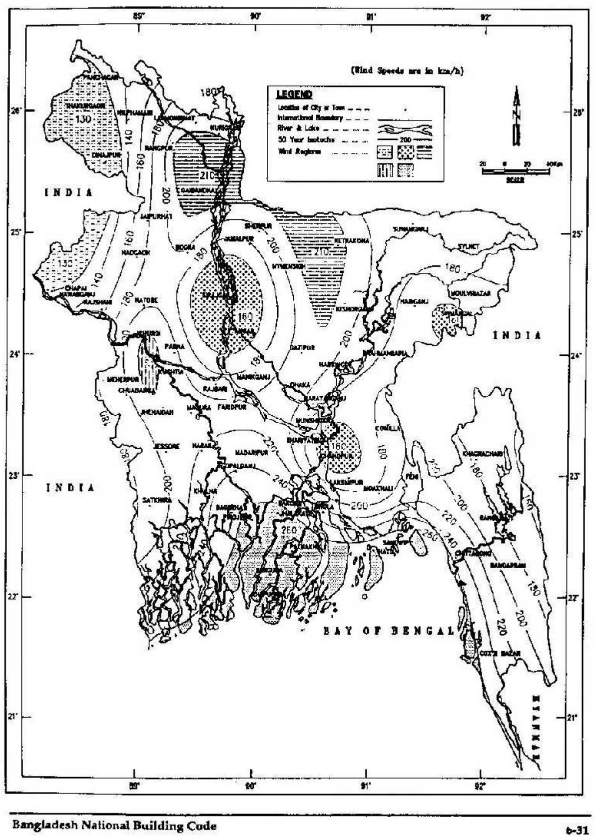
During the last few years, a number of projects have been undertaken in different parts of the world aimed at developing techniques for reducing the vulnerability of non-engineered construction against extreme winds (NIBS, 1977). Most of the houses of rural Bangladesh are designed and built by owners or artisans. Well documented literatures regarding this type of housing is unavailable in Bangladesh. There is a necessity for bridging this gap by transferring technology to the people, mostly living in the rural areas, who are actually involved in non engineered construction. The following steps are proposed by Choudhury (1999) which may be adopted:

Translate the guidelines into Bangla. Train the trainers by BUET, HBRI in association with NGOs. Training programmes for the artisans (masons, carpenters etc.). Use of mass media to demonstrate good practices. Experiences from other countries shows that post-disaster reconstruction provides an excellent opportunity for introducing improvements in housing technology.

Wind risk areas

Winds in the first 1000m of the atmosphere are of boundary layer nature. This means that shear forces within the wind flow are significant. Wind velocity can be considered as a low frequency velocity-time wave superposed with a higher frequency, velocity-time wave. These high frequency waves represent wind-gust, which is recorded as an average velocity for a particular time interval.

Recently a comprehensive National Building Code has been formulated (BNBC, 1993) in Bangladesh. Figure 1 shows the basic wind speed map of the country as presented in BNBC.



Figue 1 : Basic wind speed map of Bangladesh

Improved domestic construction

According to a recent ADB report (Lewis and Chisholm, 1999), 82% of lwellings in Bangladesh are in rural areas, 75% of rural areas are of kutcha onstruction (non-masonry; bamboo, woven bamboo, etc.), and that 23% of ırban and more than 40% of rural dwellings are of a temporary nature.

Evidence from the field in cyclone-prone areas indicates that there is a ocially perceived need for improved construction of domestic dwellings and hat assistance to build stronger homes would be appropriate. Traditional naterials for domestic construction include bamboo and jute poles, woven amboo, mud, thatch, timber, very often in combination with cgi sheet, and in arying combinations and preferences overall according to region and material vailability. Generally, floor is composed of mud plinth or raised timber, frame s made of bamboo poles or jute poles, walls are made of woven bamboo, mud r cgi sheet and roof is composed of thatch or cgi sheet.

Lewis and Chisholm (1999) proposed several improvements. Buildings hould be sited with trees so as to protect each other. Clustering achieves a legree of mutual protection that linear layouts do not. Protection from normal vind and weather as well from cyclonic winds is also advantageously achieved. rame will be improved with the inclusion of cross bracings as shown in Figure . Frame members are normally lashed together with jute rope, they can be ubstituted with galvanised wires as shown in Figure 3. Walls and openings can e improved by placing door in the centre of the wall and placing a small vindow opening in the rear wall as shown in Figure 4. The roof system can be nproved by increasing the pitch of the roofs to between 30 to 40 degrees, tying lown the thatch, improved fixings for cgi sheet and so on.

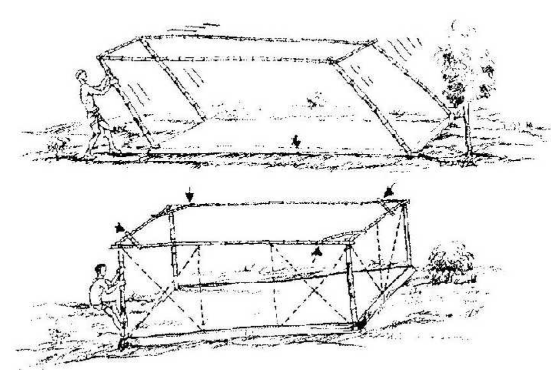


Figure 2 : Frame with and without lateral bracing

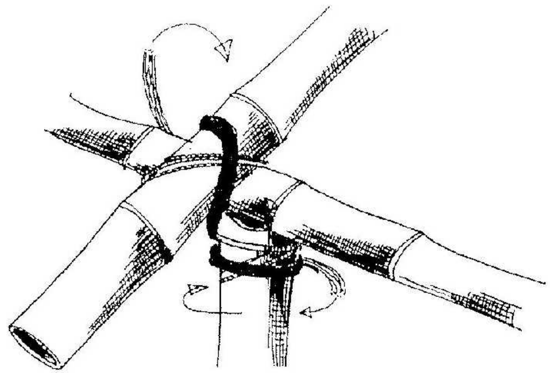


Figure 3 : Frame connections

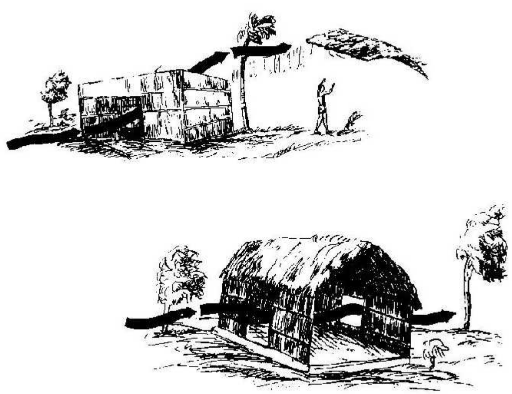


Figure 4 : Locations of doors and windows

Wind tunnel test

Static loading on a rural hut is unable to replicate the actual behaviour of the hut due to high wind generated during cyclonic storms. It is difficult to simulate dynamic load due to wind, rate of application, etc. by performing static load test on hut. To get the actual behaviour of a rural hut under dynamic wind load is possible in a wind tunnel experiment. Since BUET does not have this facility, the test will be carried out in the University of Exeter, UK. There are mainly two types of wind tunnels, open-jet and closed-jet. The other main type of wind tunnel is the meteorological wind tunnel. The wind tunnel that will be available for this project at the University of Exeter is a closed jet tunnel with working section approximately 0.5m high by 0.8m breadth and 1.2m in length.

Figure 5 shows the wind tunnel to be used in this research work at the University of Exeter. The disadvantage of this type of wind tunnel is that the working section is confined by four walls. Forces and pressures are artificially high in closed jets because the air is constrained by the walls as it flows past the model.

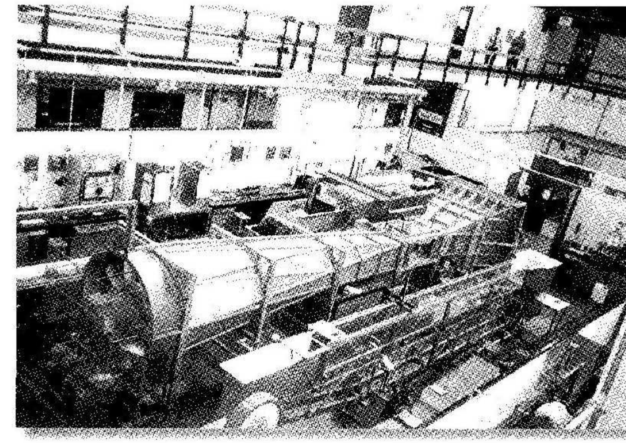


Figure 5 : University of Exeter's wind tunnel to be used in BUET's research

Modelling consideration

Despite many codes of practice, modelling is still acknowledged as the only accurate means of assessment for wind loads on buildings. Comparatively few codes of practice deal with extreme wind conditions and suitability of western codes for tropical countries is uncertain.

Limitation of physical and mathematical models

In order to determine the behaviour of engineering processes, components or structures, numerical or physical modelling is usually undertaken. The scale of a model should be as large as possible but practical laboratory constraints will dictate the model size. According to Muller (Noor and Boswell, 1992), when an entire prototype is the object of investigation, scales of 1:10 or smaller must be used.

There are a number of disadvantages while considering tests on physical models. The accuracy of the measured results is often inadequate and dependent on chance during carrying out of the tests. Reliable experimental results are usually only obtainable with a great deal of time and effort. Every experimental analysis demands a test set-up and the carrying out and evaluation of measurements. With model tests, in addition, the making of a model becomes necessary. All this requires a lot of time and a high input of technical resources. Therefore model tests of medium-sized or small objects generally cannot be justified from the economic point of view.

Bracing patterns for rural huts

Non-engineered housing in cyclone hazard zones of Bangladesh is characterized by absence of any element to resist racking forces. Introduction of some elements of wind resistance in their construction could substantially improve their performance under extreme wind. The traditional housing with simplest form has a skeleton of bamboo framing. Four corner poles are framed at lower level of roof by four other struts in the horizontal plane. The pitched roof is usually covered by indigenous material like hay. Wall claddings are usually stitched out of bamboo strips.

In order to understand the wind resistance potential, Anwar (1999) analysed the basic frame plus several variations of the basic frame with wind braces to estimate the lateral and torsional stiffnesses. Figure 6 shows the basic frame and four other frames with wind braces. The plan dimensions and height of the basic frame used by Anwar (1999) were 3m. The cross-sectional area and moment of inertia of the poles and struts were taken as 100cm2 and 890 cm4 respectively. The cross-sectional area and moment of the inertia of the braces were 26 cm2 and 55 cm4 respectively. Numerical analysis of the above five systems by the program SAP has shown that the lateral stiffness does not improve at all by providing horizontal cross brace at top only. Introduction of vertical cross braces around the basic framing improves the stiffness several times. For wind tunnel experiment these five schemes shown in Figure 6 will be used on the housing units to be tested.

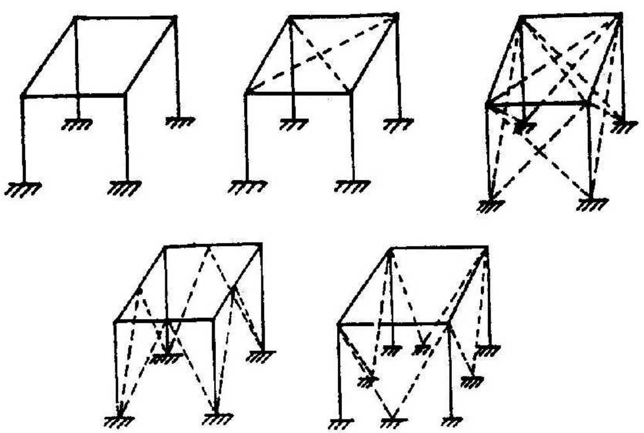


Figure 6 : Basic frame and options for wind bracing

Selected rural hut for wind tunnel test

Despite many codes of practice, modelling is still acknowledged as the only accurate means of assessment for wind loads on buildings. Comparatively few codes of practice deal with extreme wind conditions and suitability of western codes for tropical countries is uncertain.

In order for any wind-tunnel flow to exactly represent a prototype flow with a different scale length, the two flows must be (1) geometrically similar, (2) dynamically similar, (3) thermally similar and (4) their boundary conditions must be similar. These similarity conditions are described by performing an inspectional analysis of the governing equations of motions (continuity, momentum and energy). Unfortunately, exact simulation of the atmospheric boundary layer in a wind tunnel is not presently possible. As a result, approximate or partial similarity is achieved by requiring exact equality for the most important factors while those of lesser importance are approximated.

The wind tunnel to be used to simulate flow conditions in this experimental investigation is a low-speed wind tunnel at the Fluid Dynamics Laboratory, School of Engineering, the University of Exeter, UK. Traditionally, the velocity in the tunnel is measured by an inclined water-column pressure system. In addition to that a Pitot-static tube connected to a micromanometer system is used to calibrate the tunnel velocity.

Figure 7 shows the full-scale rural hut. The height, breadth and length of the full-scale model are 3m, 2.4m and 4.6m respectively. For research with rural hut in the wind-tunnel experiment a 1:20 scale model has been selected. The detailed information of the model rural hut for wind-tunnel test is presented in Table 1. The table shows the types of structures to be tested, velocity under which the tests will be performed, different roof pitch to be used and wind incident angles.

Table 1 : Information of one-twentieth scale model rural hut

Height = 0.125m, breadth = 0.15m and length = 0.25m	
Types of structure	Rigid and flexible
Wind velocity (m/s)	10, 15, 20, 25, 30 and 35
Variation of roof pitch (degrees)	30, 35, 40 and 45
Angle of incidence of wind on model (degrees)	0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300 and 330

Conclusions

A detailed wind tunnel experiment on a typical Bangladeshi rural hut is planned. Different improvements of rural huts as suggested by different researchers based on their experiences and numerical studies will be verified during the wind tunnel experiment. The main emphasis will be on lateral bracing system of the hut, connections between frame and roof, uplift mechanism of the roof, placement of doors and windows etc.

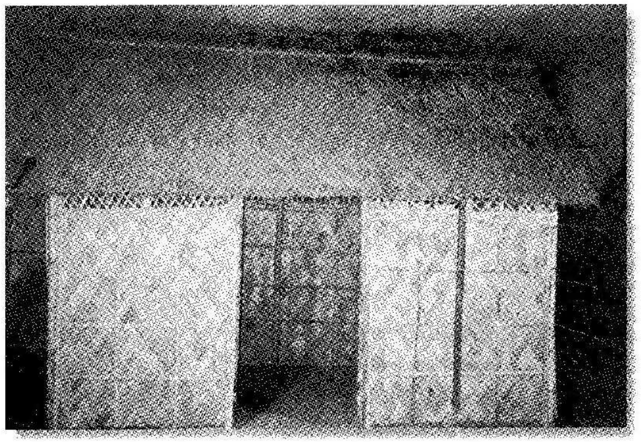


Figure 7 : Full-scale model rural hut

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