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EXPERIMENTAL STUDY ON THE WIND-EFFECTS ON BANGLADESHI RURAL HUT

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Introduction

The majority of houses in the wind hazard zones of Bangladesh fall under the category of non-engineered structures. These are the traditional self-built housing for the poorest class of people. These structures, mostly with thatched roofs, are not covered in 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 minimize loss of life and property. With a view to improving the wind-resistance potential of rural houses, wind tunnel experiments have been conducted on a rural house model at different flow conditions with different bracing systems. The effect of turbulence and the bracing systems on the lateral displacement of the house model has been discussed.

Experimental set-up

The experiment was conducted in a wind tunnel of the school of engineering, University of Exeter, UK. The wind tunnel is an open circuit type and has a working section of 0.50 m high, 0.75 m wide and 1.5 m in long. The maximum wind speed of the tunnel is 30 m/s.

In the experiment a model of Bangladeshi rural hut was made based on a scale of 1:20. The model plan and elevation are shown in Figs. 1. The plinth of the house has been simulated with a 18 cm $\times$ 29 cm timber of 2.0 cm thick. Round holes of 25 mm diameter are drilled on the timber base at the column locations shown as black dots in Fig. 1a. The large diameter holes are provided to allow movement or displacement of the supporting columns. The holes are then filled up with re-usable adhesive commercially known as Blu-Tack. Bamboo-stick columns of 5-7 mm in diameter were inserted right into the Blu-Tack. The unconfined compression test of Blu-Tack has been performed and the results are shown in Fig. 2. It has been found that the behaviour of Blu-Tack is similar to that of stiff clay. The joints where two or more member ends meet were tightly fastened to each other by using cotton ropes of about 0.3 mm in diameter. The fences of the model were made with woven plastic, which is flexible and has virtually no or very little bending resistance in and out of the plane it lies, but can take tension. The roof of the house model was made of solid card-board papers of 1.5 mm thick.

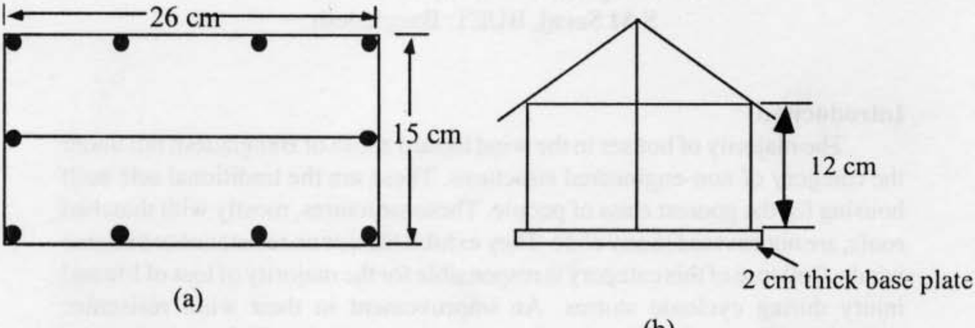


Figure 1: (a) Plan and (b) elevation of the house model

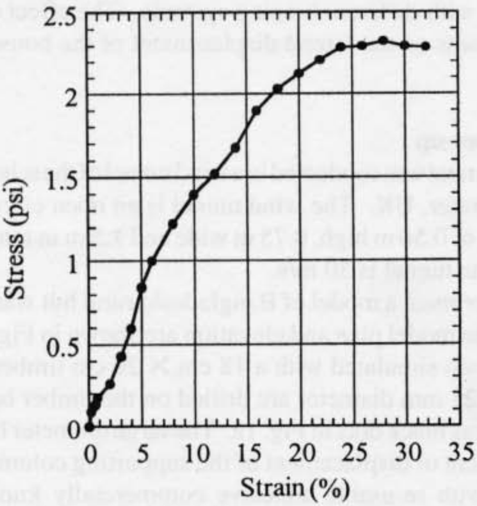


Figure 2: Unconfined compression test of Blu-Tack

Pressure measurements were done in two different approaching flow conditions described as smooth flow and turbulent flow, respectively. The turbulent flow was generated by placing a piece of timber of 25 mm thick and 65 mm high right across the tunnel width. The piece of timber was located at a distance of 1.1 m upstream of the model center. The velocity gradient of both types of flow is shown in Fig. 3.

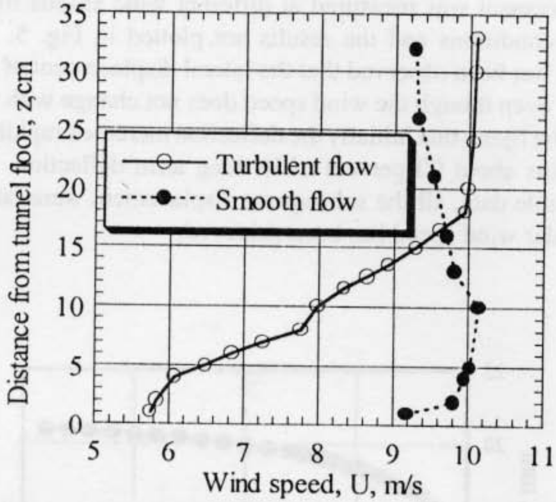


Figure 3 : Wind velocity profile at both smooth and turbulent flow conditions

Displacement of the model was measured with the help of a deflectometer dial gauge set at the mid-height of the middle of the leeward fence. As the deflectometer was set at the leeward face of the model, the interference would be minimum. The set-up of the experiment is shown in Fig. 4.

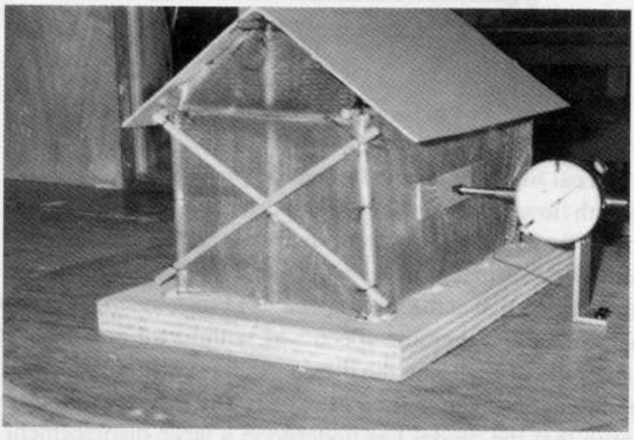


Figure 4 : Set-up of the experiment for measuring deflection of the model

Effect of storm duration on the lateral displacement

To observe the effect of storm duration on the lateral displacement on the model, displacement was measured at different wind speeds for 180 sec in smooth flow conditions and the results are plotted in Fig. 5. During the experiment, it has been observed that the lateral displacement of the model is not stationary even though the wind speed does not change with time. It can be seen from the figure that initially the deflection increases rapidly and within 60 sec it attains about 90 percent of its long term deflection. To have a reasonably stable data, all the subsequent displacement were taken at 2 min after a particular wind speed has been achieved.

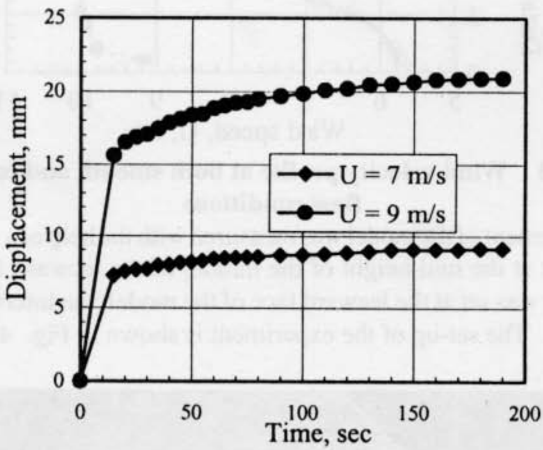


Figure 5 : Variation of displacement with time

Effect of lateral bracing on the lateral displacement

In smooth flow condition, the wind speed in the wind tunnel was gradually increased from 0 to 11 m/s at different stages. At each stage the speed was kept constant for a duration of 2 min and then the lateral displacement was recorded. It has been observed that at the wind speed of 11 m/s, the model has undergone large displacement and then the speed was withdrawn gradually at different steps and similarly at each step the displacement was also recorded. This part of the experiment has been termed as expt.1. The results are shown in Fig. 6. It can be seen that the model has undergone a large displacement and upon withdrawal of wind speed, the displacement recovery is very small.

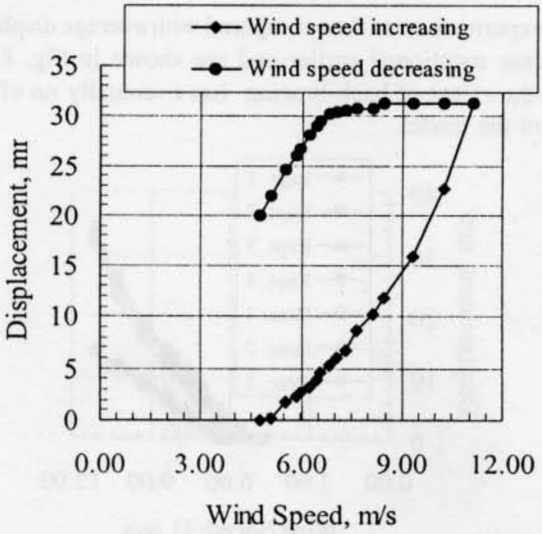


Figure 6 : Displacement of the model at different wind speed

After finishing expt.1, all the columns are pulled out of the supporting materials. The Blu-Tack is freshly inserted into the holes, and the columns of the model are placed again. Care has been taken to have similar support condition. The displacement of the house model was measured at different wind speeds (expt.2). To have an idea of the reproducibility of the model response, this has been repeated for another two times (expt. 3, expt. 4). The results are shown in Fig. 7. It has been found that the displacements vary from one experiment to another. It is understood that the variations are mainly due to the variability of the compactness of the material and also the exactness of the column locations.

Cross-bracings made of bamboo-cut-pieces of about 4 mm in diameter are then attached on two lateral sides. The ends of the bracing are tied to the frames with ropes. The displacement was measured at different wind speeds in a way similar to before and the experiment was repeated for three times. The experimental results are also shown in Fig. 7 as Brac1, Brac2, Brac3. It is seen that there are also variations in model response from one experiment to another in this braced condition. But, it is clear from the figure that the introduction of side bracing reduces the lateral displacement of the model to a great extent. In addition to the side-bracing, cross-wise bracings are also provided at the backside of the house model, and the lateral displacement was measured at different wind speeds for three different experiments. Average displacement of these three experiments are then compared with average displacement of the side bracing case mentioned earlier and are shown in Fig. 8. It has been observed that the effect of back-bracing has eventually no effect on lateral displacement of the model.

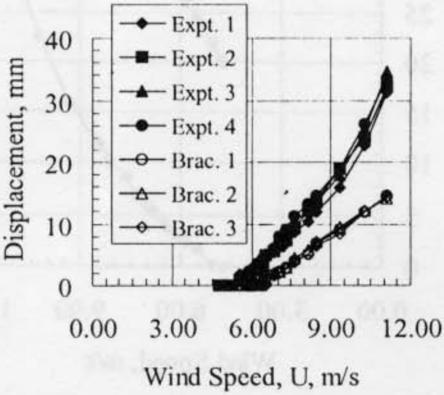


Figure 7 : Effect of lateral bracing on the lateral displacement

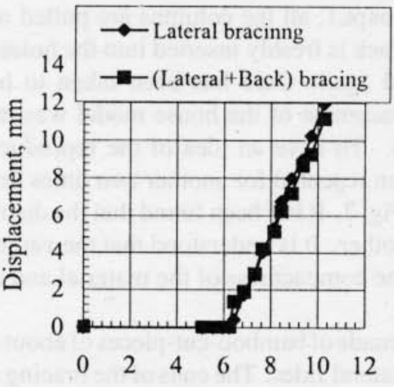


Figure 8 : Effect of back bracing on lateral displacement

Diagonal tie ropes of 3 mm diameter tied to the frame were also tried in place of bamboo bracing. Average displacement of the house model were then compared with the displacement obtained in case of unbraced and braced model and the comparison are shown in Fig. 9. It can be seen that the tied ropes are most effective in suppressing the lateral displacement. The better performance of tie bracing over the bamboo bracing can be thought as the tie ropes could easily be placed more tightly than the bamboo bracing, otherwise the performance of both the bracings were expected to be the same.

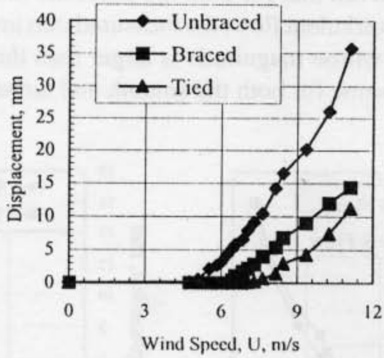


Figure 9 : Effect of tied rope on the lateral displacement

Effect of incident wind angle

To observe the effect of incident wind angle, displacement of the braced model was also measured for wind with an horizontal angle of 45 from the normal to the lateral side of the model and the result has been compared with its 0^{o} wind yaw angle counterpart . It has been observed (Fig. 10) that the displacement of the model response is less for the yawed wind as it was expected.

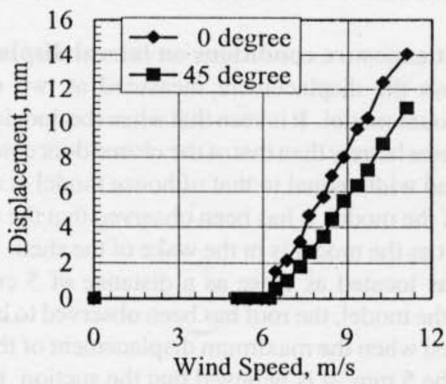
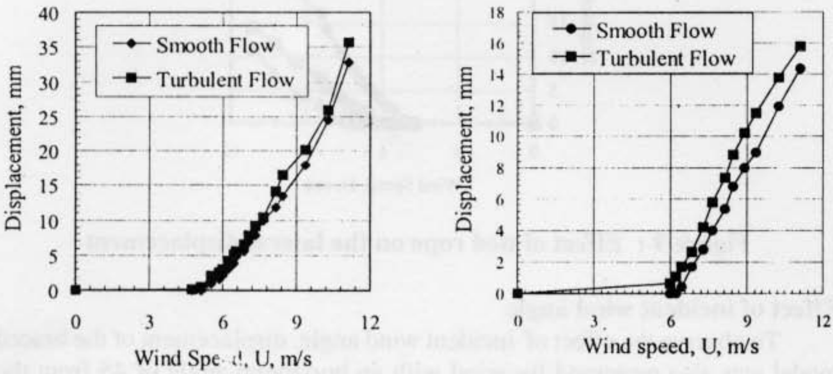


Figure 10 : Effect of yawed wind on model response

Effect of incidence turbulence on the model displacement

To understand the effect of turbulence on the model response, the displacement of the model was measured for both in smooth flow and turbulent flow for both the braced and unbraced models. The results are shown in Fig. 11. It has been observed that for both the cases the turbulence increases the model responses. In turbulent flow, the measured maximum displacement was effected by the gust whose magnitude is larger than the gradient wind speed which is almost the same for both the smooth and turbulent flow conditions.



(a) (b)

Figure 11 : Effect of turbulence on the model response, (a) braced condition, (b) unbraced condition

Effect of different exposure conditions on lateral displacement

Fig. 12 shows the displacement measured at two different exposure conditions of the house model. It is seen that when the door is open the response of the model increases largely than that of the closed door condition. Employing a shed of height and width equal to that of house model at a distance of about 40 cm upstream of the model, it has been observed that the model undergoes a large displacement as the model is in the wake of the shed. On the other hand, when the shed was located as close as a distance of 5 cm upstream of the windward face of the model, the roof has been observed to be lifted at the same gradient wind speed when the maximum displacement of the model house has been observed to be 5 mm. It is believed that the suction just downstream of the shed is mainly playing the role in producing large uplift force.

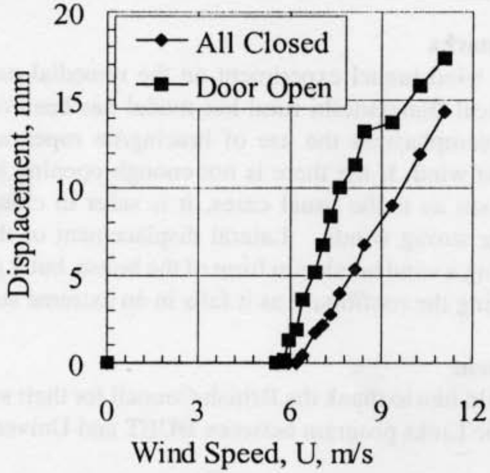


Figure 12 : Effect of exposure condition

Hysterisis behaviour of the house model

Histerisis behaviour of the house model is shown in Fig. 13. It can be seen from the figure that the displacement recovery is very small. Another important characteristics as can be observed is that for every cycle of loading the displacement of the house becomes larger than its previous cycle. This type of behaviour has also been noticed during full scale house test as described in Roy et al. (1999).

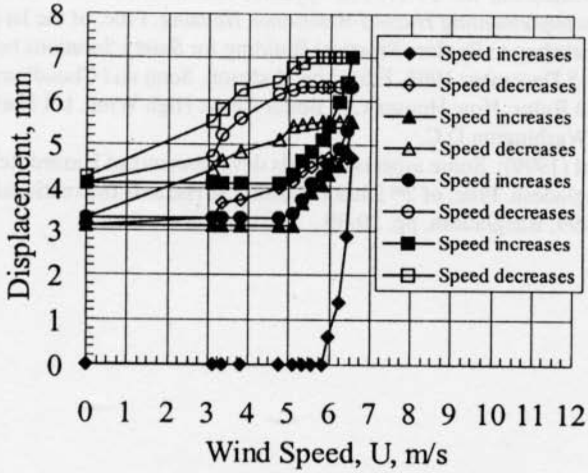


Figure 13 : Hysteris behaviour of house model

Concluding remarks

A detailed wind tunnel experiment on the remedial measures of wind effects on a typical Bangladeshi rural hut model has been conducted. This research work reemphasizes the use of bracing/tie ropes to have a strong safeguard against wind. If the there is not enough opening to pass the wind through the houses as is the usual cases, it is safer to close the doors and windows during strong winds. Lateral displacement of the house can be reduced by placing a wind breaker in front of the house, but it greatly enhances the risk of uplifting the roof/house as it falls in an extreme suction region.

Acknowledgement

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References

Anwar, A M M T (1996). Wind Resistance of Non-engineered Housing. *In implementing Hazard-Resistance Housing*, Proc. of the Ist Int. Housing & Hazards Workshop to Explore Practical Building for Safety Solutions held in Dhaka, Bangladesh, 3-5 December 1996, Editedby Hodgson, Seraj and Choudhury, pp. 23-27.

BNBC (1993). Bangladesh National Building Code, 1993. HBRI-BSTI.

Choudhury, J. R. (1996). Design and Construction of Houses to Resist Natural Hazards *In implementing Hazard-Resistance Housing*, Proc. of the Ist Int. Housing & Hazards Workshop to Explore Practical Building for Safety Solutions held in Dhaka, Bangladesh, 3-5 December 1996, Edited by Hodgson, Seraj and Choudhury, pp. 11-17.

Lewis, J. & Chisholm, M. P. (1996). Cyclone-resistant Domestic Construction in Bangladesh. *In implementing Hazard-Resistance Housing*, Proc. of the Ist Int. Housing & 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.

NBS (1977). 43 Rules: How Houses Can Better Resist High Wind. US National Bureau of Standards, Washington D.C.

Roy U. K. et al (1999): Some aspects towards developments of Hazard Resistant Rural Homes in Bangladesh. Proc. of 2nd Dhaka Housing & Hazards International Seminar, 6-8 February, 1999, Bangladesh, pp. 29-39