PRESSURE DISTRIBUTION CHARACTERISTICS ON A TYPICAL BANGLADESHI RURAL HOME

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Introduction

Housing to mankind is the basic primary need next to food and clothing, clear air and potable water, being the very essentials for existence. In Bangladesh, almost 70% of the population in the rural sector and 50% of the population in the urban sector is living below the poverty line with earnings too little to pay for all needs. It is this group of people most impoverished that is to be provided with good housing. According to recent ADB report (Lewis and Chisholm, 1999), 82% of the dwellings are in rural areas. About 75% of rural areas are of kutcha construction (mud, bamboo, woven bamboo, etc.), and that 23% of urban and more than 40% of rural dwellings are of a temporary nature. They can rarely survive against even a moderate intensity storm. Evidence from the field in strong wind-prone areas indicates that there is a socially perceived need of more engineering knowledge and improved construction of domestic dwellings.

Strong wind is an annual natural hazard in Bangladesh due to its geographical location. On the other hand, most of the existing houses and houses which are going to be built in the next few decades are likely to be non-engineered, mostly with thatched roofs and are vulnerable to wind. Strong wind is causing immense loses of rural dwellers by making their houses collapse fully or partially by lifting of roof, etc. With a view to assessing the vulnerability of collapsing of rural houses due to strong wind, an experimental study has been conducted by measuring pressures at different locations on a typical Bangladeshi rural house model at different exposure conditions, wind directions, roof slopes and flow conditions. It has been observed that even without specific openings, a small amount of internal pressure exists because of passing of air through the small openings at different joint locations. High lifting pressures were noticed at the leeward fence and roof of the house model with an exposure condition of door is kept opened and window is closed. Based on experimental results, roof slopes ranging from 25^{O} to 40^{O} are considered to be effective for the construction of rural homes.

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 0.50m high, 0.75 m breadth and 1.5 m in length. The maximum wind speed of the tunnel is 30 m/s.

In the experiment a house model as shown in Fig. 1 was made based on a scale of 1:20 of a typical Bangladeshi rural hut. The model placed in the tunnel always partially obstructs the passage of air causing the flow to accelerate. When this obstruction or blockage is substantial, the flow around the model and the model's aerodynamic behaviour are no longer representative of the prototype condition. Although the blockage in this experiment is about 10%, no corrections are made to the observed data. The model plan and elevation are shown in Figs. 2. The black dots in Fig. 2a denote the column locations.

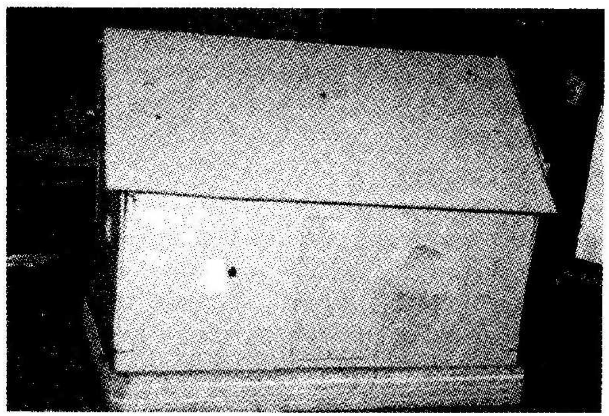
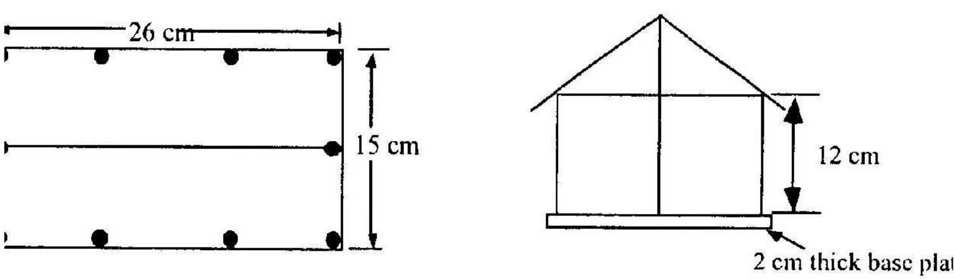


Figure 1 : House model used in the experiment



(a) (b)

Figure 2 : (a) Plan, and (b) Elevation of the house model

The plinth of the house has been simulated with a 15 cm × 29 cm timber of 2 cm thick. The columns of the house model were made of bamboo stick of 6-8 mm in diameter. Round holes of 6-8 mm diameter are so drilled on the timber base that the columns can be tightly inserted into these holes. The joints where two or more member ends meet were tightly fastened each other by using cotton ropes of about 0.3 mm in diameter. The fences and the roof of the house model were made of solid cardboard papers of 1.5 mm thick.

Pressure measurements were done in two different approaching flow conditions described as smooth flow and turbulent flow, respectively. The turbulent flow has been 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.

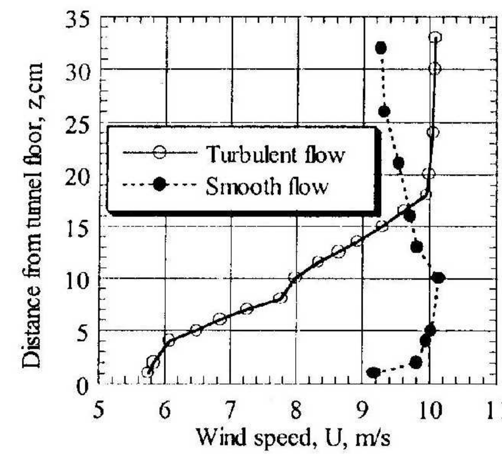


Figure 3 : Wind velocity profile at both smooth and turbulent flow conditions

Measurement of Pressure

Inside and outside pressures at different locations on the model fence and roof were measured at a gradient wind speed of 10 m/s with pressure taps. Inside and outside diameter of the pressure tap were 3 and 5 mm, respectively. There were ten locations of pressure measurement number from 1/11 to 10/20 as shown in Fig. 4. There were in total 20 pressure taps at ten locations. Ten of the twenty pressure taps numbering from 1 to 10 were used to measure the outside pressure and the rest ten numbering from 11 to 20 were used to measure the inside pressure. Fig. 5 shows the measured pressure at different locations for a roof slope of 35°. Resultant pressures are calculated by deducting the inside pressure value from that of outside. Here from all the pressures as presented in this paper represent the resultant pressure. The negative value of the pressure indicates suction.

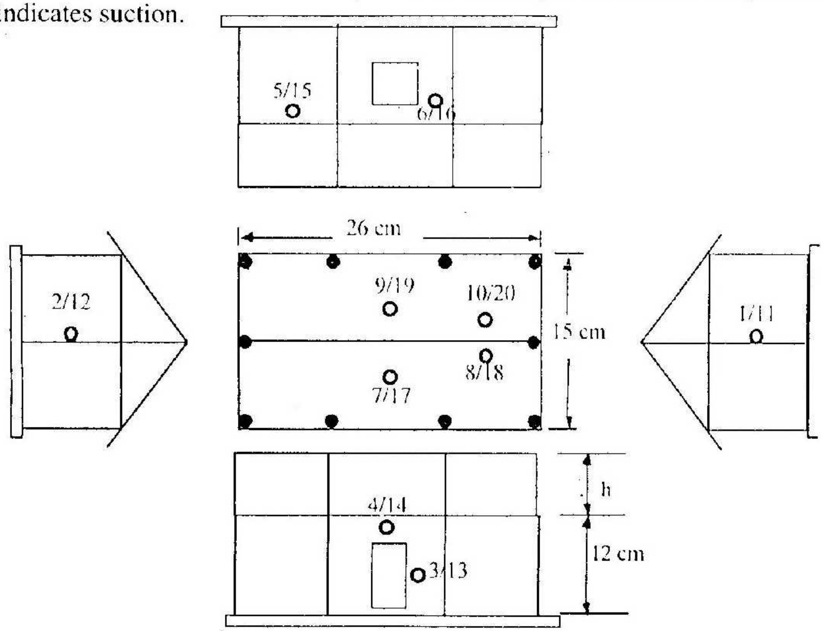


Figure 4 : Schematic diagram showing locations of measurement of pressure on fence and roof of the model

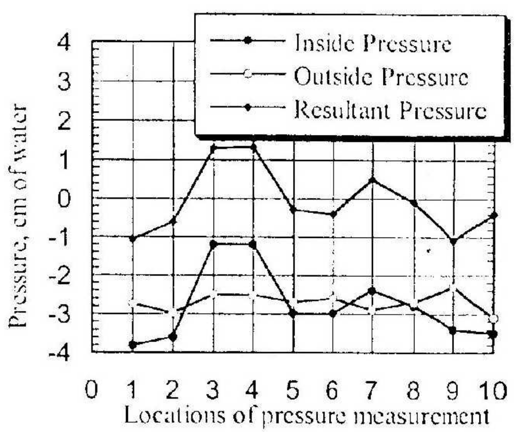


Figure 5 : Inside, outside and resultant pressure at different locations

Effect of exposure conditions on pressure

Internal and external pressure were measured at all the locations at different exposure conditions. Four different exposure conditions were studied in the experiment. These are: (i) door (D) is opened but window (W) is closed, (ii) both door and window are opened, (iii) door is closed but window is opened, and (iv) both door and window are closed.

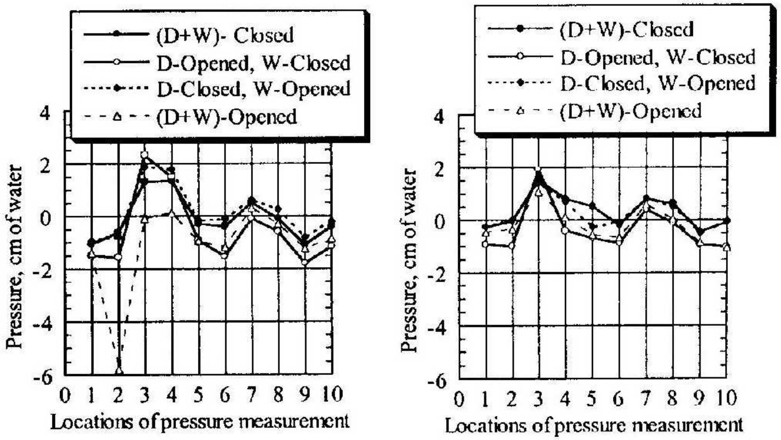
It can be seen from Fig. 6a that suction occurred at all the places except the locations 3 and 4 on the windward fence where pressures are registered for almost all the exposure conditions. At both the windward and leeward locations on the roof, maximum suctions are found for the exposure condition of door is opened but window is closed (exposure: i). Upon opening the window at the leeward side (exposure: ii) reduces the uplifting suctions at the roof but its magnitudes are still higher than the condition of both door and window are closed (exposure: iv) or door is closed but wind is opened (exposure: iii). Similar observations has also been found for the turbulent flow conditions as can been seen from Fig. 6b. Hence, it is concluded from this observation that if there were not sufficient openings on the fences on both windward and leeward side, it would be better to close the door and window during storms.

Effect of roof slope on pressure

Pressure measurements were done at all the locations for different exposure conditions for each of the roof slopes,Q of 25^O, 35^O, 40^O, 45^O. It can be seen from Fig.7a that at the locations 9 and 10 on the leeward roof which is most susceptible to lifting off during storms, the pressures are more or less same of all the pitch angles under consideration with an exception of slight increase in suction at,Q =45^O in turbulent flow condition. Similar is the case for the windward roof. Hence roof slopes ranging from 25^O to 40^O are considered to be effective for the construction of rural houses.

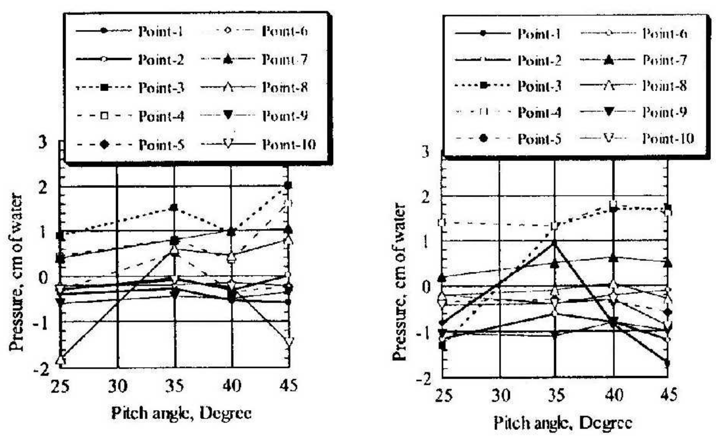
Effect of wind yaw angle on pressure

Pressure measurement has been performed at different locations for different wind yaw angles. Here, wind yaw angle is defined as the horizontal wind incident angle from the normal to the fence with door. Fig. 8 shows the pressures at all the locations in smooth flow condition with the exposure condition of both the door and window are closed (exposure: iv) for, Q = 25^O. It has been observed that at location 9, the suction gradually decreases with the increase of wind yaw angle as expected. No specific trend has been observed at location 10. Wind yaw angle of around 0^O is the most severe condition for the uplifting of roof at the leeward side.



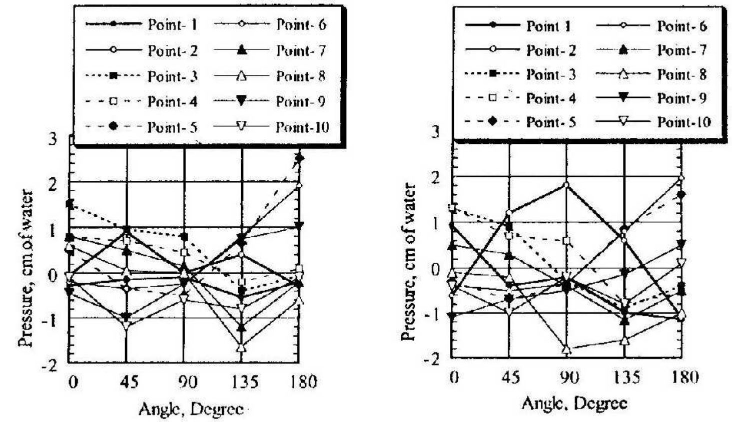
(a) (b)

Figure 6 : Resultant pressure at different locations with exposure condition of no openings in the model (exposure: iv) and horizontal wind yaw angle of 0^O,(a) smooth flow, (b) turbulent flow



(a) (b)

Figure. 7 : Resultant pressure at all locations for different roof slopes with the yaw angle of 0^O and exposure condition of all closed (Exposure: iv), (a) smooth flow, and (b) turbulent flow



(a) (b)

Figure 8 : Pressure at all locations for different yaw angles with the exposure condition of both door and window are closed (exposure: iv), (a)smooth flow, (b) turbulent flow

Concluding Remarks

A detailed wind tunnel experiment has been conducted to measure the pressures at various locations on a scaled model of a typical Bangladeshi rural hut for different exposure conditions. Based on the experimental results and reasoning, it has been thought that if 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. Roof slopes ranging from 25^O to 40^O are suitable against strong winds as no significant difference of suctions were observed at the leeward side of the roof. Lifting forces on the roof are very much dependent on the wind yaw angle and large suctions are casued by the wind coming from the direction normal to the fence.

Acknowledgement

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