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WIND RESISTANCE OF NON-ENGINEERED HOUSING

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Introduction

Devastating cyclones originate between 5 degrees and 30 degrees latitude on either side of the equator. Bangladesh, lying between 20 and 27 degrees on the north falls well within the zone. Gray (1967) has shown that the highest frequency of cyclones over 5 degree squares per 25 years occurs in the Bay of Bengal. For that reason, the cyclone is an annual phenomenon for coastal Bangladesh which suffers from colossal losses, both in terms of life and of property, almost every year due to this natural hazard.

The majority of housing in cyclone-prone zones is non- engineered thatched construction. These structures have virtually no lateral load resistance mechanism. They can rarely survive even a moderate intensity cyclone. Total collapse of the structures causes loss of life as well as of properties. The objective of this paper is to find ways and means of enhancing the lateral load resistance potential of such non-engineered constructions.

Recent cyclones

Of the many cyclones which have hit Bangladesh in recent years, those of 1970, 1985 and 1991 were the most destructive. The 1970 cyclone is estimated to have caused a death toll between 300,000 and 500,000 and colossal property damage. On the night of 29th April 1991, the coastal Bangladesh was lashed by the century's most devastating cyclone. This calamity lasted for about five hours during which wind velocities rose to 235 kmh and a tidal surge ranging in height between 17' and 22' washed the coastal belt. According to government estimates, a total of 10 million people were affected of whom 138,882 lost their lives. Out of 1,702,358 affected houses, 819,608 were totally destroyed. Damage was costed at two million dollars.

Mitigations

A reduction in loss of life and property is possible by taking appropriate measures. Mitigations may be pre-hazard or post-hazard. Pre-hazard mitigations include mitigation of cyclone, exposure and vulnerability. Post-hazard mitigations cover relief and rehabilitation intended to reduce consequential losses.

To prevent a cyclone occurring is not possible. However, efforts have been made by researchers to find ways of reducing the intensity of cyclones. Although occasional successes were reported (Gentry, 1970, Gray et al., 1976), the subject still needs a lot of input.

People living in the coastal areas of Bangladesh are exposed to high risk. Early warning of cyclones, evacuation of people and construction of cyclone shelters are being practiced as effective means of limiting the exposure of these people to cyclones.

The Bangladesh National Building Code (HBRI, 1993) provides guidelines for wind resistant design considering appropriate wind speeds. The majority of structures, however, are non-engineered and this group remains outside the code coverage. The question of mitigation of vulnerability, therefore, cannot be addressed properly without reducing the vulnerability of non-engineered structures to extreme wind.

Housing practice

Structures built in the hazard zones of Bangladesh may be classified as engineered and non-engineered. Engineered structures are designed to sustain extreme wind for the location and perform well in adverse conditions.

The non-engineered category of structures includes the traditional self-built housing of the poorest layer of the population. These are not covered by any code nor do they ever attract any attention from qualified engineers. 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. Therefore, any improvement in their wind resistance would significantly contribute to minimising loss of life and property.

Improvement for wind resistance

Some studies have been carried out regarding construction of wind-resistant low-rise, low-cost housing in Philippines and in Jamaica (Kunar, 1995, Booth & Martinez-Rueda, 1995). Works are also reported on cyclone-resistant houses with thatched roofs and mud walls in coastal India (Mathur, 1993) and on typhoon resistant small dwellings in Vietnam (Norton & Chantry, 1993). All these works deal with the problem characterised by local factors and have little in common with each other. Traditional non-engineered houses in Bangladesh differ significantly from those in other countries. The problem of cyclone-resistance of these structures, therefore, has to be addressed considering local characteristics.

Non-engineered housing in the cyclone-hazard zones of Bangladesh is characterised by the absence of any element to resist racking forces. Introduction of some elements of wind resistance in their construction could substantially improve performance under extreme wind.

Traditional Bangladeshi housing is very light and fragile. The simplest form has a skeleton of bamboo framing. Four corner poles are framed at lower level by four struts in the horizontal plane. The pitched roof is usually covered by indigenous material like dry grass. Wall claddings are usually stitched out of bamboo strips. This form of framing is vulnerable to wind speeds exceeding 40 mph (65 kmh).

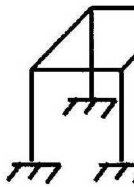
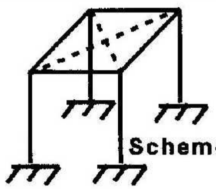
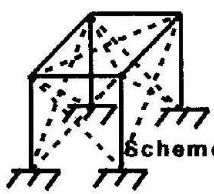
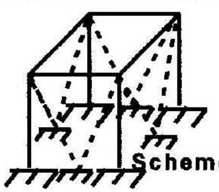
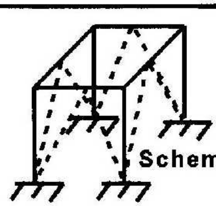
In order to understand the wind resistance potential, the basic frame and several options of the basic frame with wind braces were analysed by SAP to determine their lateral and torsional stiffnesses. Both the plan dimen-sions and height of the basic three-dimensional rectangular frame were assumed to be 10'. The cross sectional area and moment of inertia of the poles and struts were taken as 16 in^2 and 21.33 in^4 respectively. Five schemes were analysed. The basic scheme has no wind brace while the other four have some type of wind brace. Values of lateral stiffness, K_B and torsional stiffness K_T and the schemes themselves are shown in Table 1.

It is observed that the lateral stiffness does not improve at all by providing horizontal cross bracing at the top (scheme 2). The improvement in torsional stiffness is only about 26%. Introduction of vertical cross braces around the basic framing (scheme 3) improves both lateral and torsional stiffnesses by more than 100 times. Use of V-bracing (scheme 4) or inverted V-bracing (scheme 5) around the basic framing improves the lateral stiffness by more than 50 times and the torsional stiffness by more than 30 times. Inverted V-bracings are seen to be more effective than V-bracings. They are also more convenient from the point of view of providing door and window openings.

Based on the above investigations and on general engineering philosophy, the following measures are recommended to improve the cyclone resistance potential of non-engineered housing :

- Bracing of corner poles in vertical planes by cross bracings or inverted V-bracings;
- Keeping vertical rise to horizontal spread ratio of pitched roofs at 2:3;
- Minimise roof overhangs beyond vertical claddings;
- Adequate anchoring of roof and vertical claddings to basic frame and bracings;

Table 1 : Lateral & Torsional Stiffnesses for Different Bracing Schemes

Schemes	Lateral stiffness K_B [k/inch]	Torsional stiffness K_T [k-inch/rad]
 Scheme 1	3.11	$3.55x10^4$
 Scheme 2	3.13	$4.46x10^4$
 Scheme 3	318.07	$3.98x10^6$
 Scheme 4	155.18	$1.13x10^6$
 Scheme 5	174.46	$1.29x10^6$

- Minimising door and window openings and securing those with storm shutters;
- Adequate anchoring of vertical poles into ground and painting with bitumen and wrapping by polythene of the underground segments.

Conclusions

The lateral and torsional stiffnesses of basic framing of non-engineered houses are found to increase many-fold by introducing vertical cross bracings or inverted V-bracings. This may substantially improve the wind resistance potential of such housing. A set of guidelines based on engineering principles is proposed to enhance wind resistance potential of non-engineered housing. Different government agencies and NGOs involved in cyclone mitigation efforts may play a key role in securing implementation of these guidelines during construction of housing by ordinary people. This may ultimately lead to a substantial reduction in loss of life and property during cyclone disasters.

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Notations

K_B Lateral stiffness

K_T Torsional stiffness