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A study on the design guidelines of conceptual prototype proposal for the emergency shelter of the vulnerable Rohingya community in Ukhiya and Teknaf

A. A. Rahman[1,2], S. Alam[2]

[1]Department of Architecture, BUET, Bangladesh (0422012001@arch.buet.ac.bd)
[2]Department of Architecture, MIST, Bangladesh (adeeba@arch.mist.ac.bd, shariar@arch.mist.ac.bd)

Abstract

The structural design guidelines for the emergency shelter of the vulnerable Rohingya community are important for a quick response for the post-disaster period to ensure sustenance. The shelter for 943,000 Rohingya people until October 2022 has added to the vulnerability of Bangladesh, which is the fifth most disaster-at-risk country. This paper aims to propose guidelines for the conceptual prototype design for the emergency shelter considering architectural, and structural aspects that will ensure post-disaster resiliency. The guidelines will incorporate the use of stable structures with local sustainable elements supplied by the government or non-profit organizations to help local people construct their shelters easily and effectively. The methodology includes a Literature review, Structural considerations, and Conceptual Design Proposal. The simulation analysis in ETABS and the result show the feasibility of the structural strength of the proposed prototype. The scope of this paper is guidelines for a more permanent structure with higher resilience. The lack of real-scale structural analysis of the proposed design is identified as the limitation. To conclude the research, it can be said that prototype guidelines considering multiple criteria for the post-disaster shelter can help develop a policy-based solution for better sustenance of the vulnerable Rohingya community.

Keywords: *Design guidelines; Structural analysis; Temporary shelter; Rohingya community.*

1 Introduction

A shelter gives protection from adverse climatic situations and ensures privacy and security. The concept of emergency shelter emerged from the need to provide a transitional shelter for a disaster-prone area which coincides with SDG goal 11 (Sustainable Development Goals) with the aim to reduce the disaster effects and ensure sustainability for making safe, resilient and inclusive human settlements (*Goal 11*, n.d.; M. A. Rahman et al., 2015).

Bangladesh is mostly a low land with a full opening towards the Bay of Bengal in the South, so the risk of cyclones and other disasters in the coastal areas is very high (A. U. Ahmed, 2006). From the global statistics, cyclones have the highest impact on the country among various natural disasters, and worldwide Bangladesh is most vulnerable to cyclones having approximately 2/3rd of the global deaths each year in the last 2 decades (Davison, n.d.; *World Bank Climate Change Knowledge Portal*, n.d.). Various devastating historical cyclones from before the independence (1960) till today (2023) have caused damage of different levels (minimal to catastrophic) having a variety of wind speeds (ranging from 65 km/h to 232 km/h) (*Historical Cyclones*, n.d.; Thomas, 2020).
Considering the Rohingya crisis, they are highly vulnerable to disasters like cyclones that require shelter to accommodate as a basic need (*Rohingya Refugee Crisis*, 2017; Shahpur & Wardani, 2022). From the statistics, Rohingya people require funding of approximately 7 million US dollars for preparedness in emergency situations (*Bangladesh Appeal | UNICEF*, 2022).

The previous and anticipated cyclones including Mocha of 2023 have once more brought up the issue of the necessity of low-cost emergency shelter of available materials for the coastal Rohingya communities with existing funding to give a level of shelter in the post-disaster period.

2 Aim and Objectives

The aim of this paper is to propose a temporary, sustainable structure with a stable core that is easy to construct and dismantle and may be used as a makeshift shelter during cyclones and flash floods. The objectives are:

- Identify specific structural considerations effective for cyclone-prone regions.
- Propose guidelines based on existing site context for the structural system of emergency shelters.

3 Methodology

3.1 Literature Review and Site Selection

Cyclones are a great source of hazards with socioeconomic and environmental destructions affecting the land and population by bringing strong wind, heavy rainfall, storm surge, and flood due to the Coriolis effect (Koenigsberger et al., 1975; *Tropical Cyclones*, 2020). Globally, about 60% of deaths are caused in Bangladesh (300,000 in 1970) due to cyclones of the last two decades, and the destruction is the most in the coastal regions (Hossain & Mullick, 2020; *World Bank Climate Change Knowledge Portal*, n.d.). The location of the Rohingya camps are in the cyclone-prone coastal zone at Ukhiya (76.5% Camps) and Teknaf (23.5%Camps) of Cox's Bazar (*Rohingya Refugees Population by Location at Camp and Union Level - Cox's Bazar - Humanitarian Data Exchange*, n.d.). The locations of the camps are vulnerable considering the geographical location, overpopulation, and lack of funding for building construction (Md. M. Rahman et al., 2022).

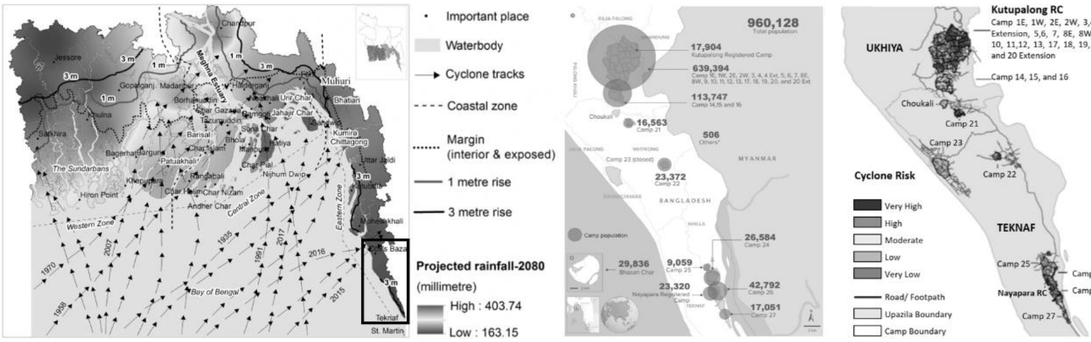

Figure 1. From left to right: Coastal cyclone susceptibility map of Bangladesh; Location of camps (till 2023); Cyclone risk map (A. Ahmed et al., 2020; "Kutupalong Refugee Camp," 2023; Md. M. Rahman et al., 2022).

The study is based on the relevant Rohingya community of the coastal area located in Ukhiya and Teknaf focusing on the site of Kutupalong RC (refugee camp) (Figure 1). It is the primary Rohingya camp in Bangladesh sprouting other camps, having cyclone risks of exposure, vulnerability, and hazard ("Kutupalong Refugee Camp," 2023).

3.2 Structural Considerations

The cyclone vulnerability is related to the structure's stability with wind forces. Structural vulnerability depends on the geography, climate, and damage that it can withstand. (Agarwal, 2007; Md. M. Rahman et al., 2022). The strong cyclonic wind has an average velocity of over 118 kph (64 knots or 74 mph) which has also exceeded historical cyclones (*Tropical Cyclones*, 2020). The extreme wind force can damage the structure, blow away the roofs, damage the windward side, and even overturn the whole building and destroy the whole structure. The heavy rainfall followed by cyclones can also cause floods (Agarwal, 2007; Mohan, 2016).

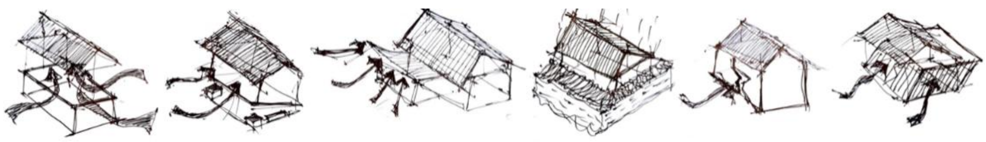

Figure 2. From left to right, Cyclone vulnerability for; roof blowing, structure overturning, veranda with light roof and flooding due to heavy rainfall, Damage on the windward side, and Structural bending.

To avoid damages and failures, some basic structural considerations are addressed in the case of shape, roof, structure, structural joining, etc. For shape, a more uniform square plan is the best option to resist the wind to avoid pressure differences to damage the structure (Taki & Doan, 2022). In terms of roofing, to avoid the uplifting wind force, a high pitch should be used (not less than 22^0) together with vertical, and diagonal bracing with rope and rafters to keep tension to sustain the roofs (Kaminski, 2018).

3.3 Conceptual Design Proposal

The design generates from the concept of resilience to ensure the sustenance of the shelter due to cyclones. The structure consists of a stable steel core and additional bamboo elements as required. The core is a hybrid prefabricated structure with a short column of 1.5'X 1.5' X 3', 6" above the ground with reinforced concrete footing (4'X4'X10") below ground level and stainless steel beams for the shell. Bamboo elements are used for the façades, roof, and additional structural support. The whole mass is raised at a height of 4' (considering annual flood). Anticorrosive paint is used in the steel beams to resist the rusting effect due to the saline water.

The HBRI (Housing and Building Research Institute) recommends introducing a 4' "Pashchati" (extended portion) around the house to increase its resistance to cyclones. For the safety of the main roof, the roofs of the "ghar"(main dwelling unit) and "Pashchati" are constructed separately.

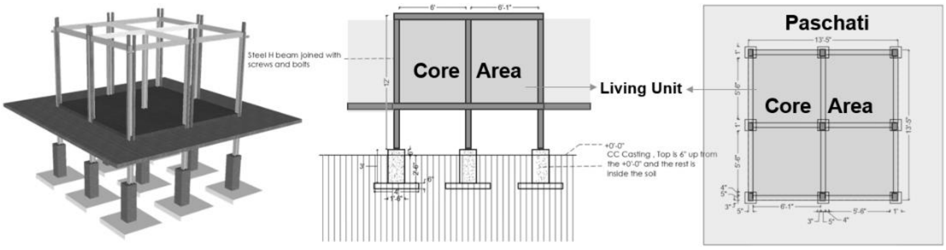

Figure 3. Conceptual Design Proposal with core structure.

An extended ceiling portion with bamboo called Macha is added above the living unit. The Macha space can be used as storage at regular times and as a temporary escape from flash floods during rainfall.

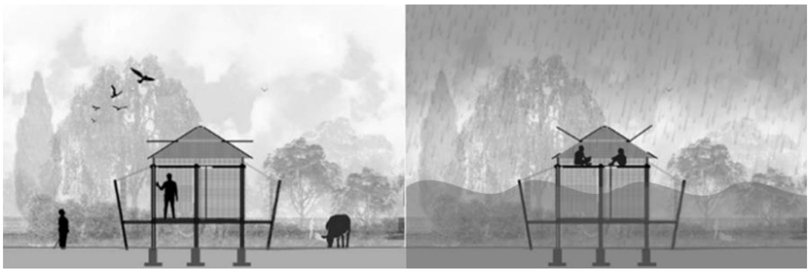

Figure 4. Sections during the dry season and storm surge.

Heavy hex structural anchor bolts are used for the structural joining of the prefabricated steel structure. Due to Steel's mechanical and physical properties, structures will give structural stability, reduce construction time, and ensure sustainability and cost efficiency throughout their lifecycle. 150 UC Steel H beams are used in the structure as columns and beams, and SS grade 304 connectors are used to join them. Local, high-quality bamboo is used for the construction of wall panels, doors, and roofs because of their cost effectiveness, availability, easy construction, and dismantling ability.

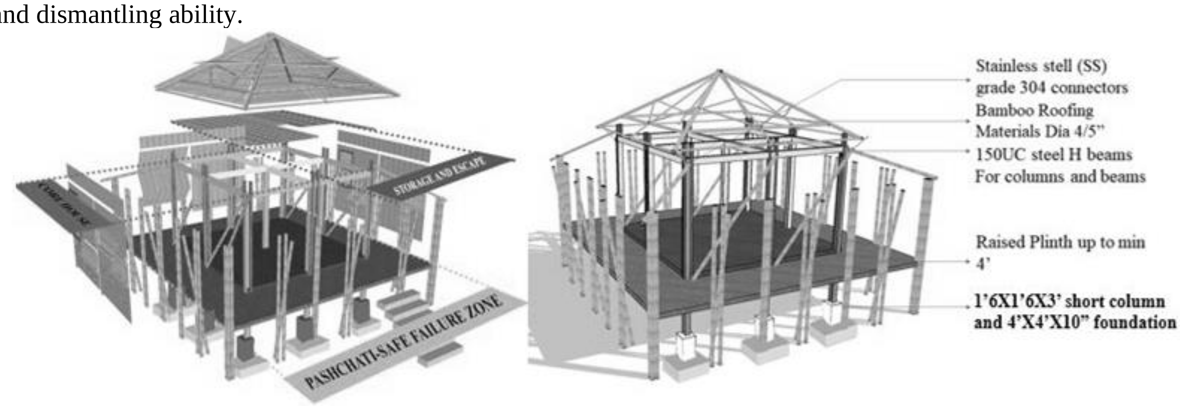

Figure 5. Proposed design with structural elements.

The resilience concept circulates with the idea of sustaining the core structure after a strong cyclone that destroys the other building elements gradually depending on the intensity of the cyclone that can be made habitable step by step with minimum cost and effort by the dwellers in the post-disaster period.

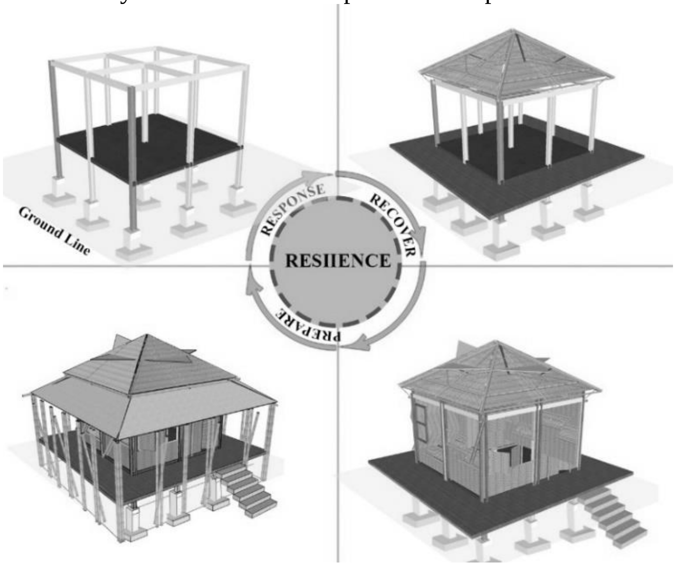

Figure 6. Steps and concepts considered for the design proposal.

The estimated cost is analyzed to check the feasibility of the construction and to identify the portion of the construction that needs funding and the amount of financial help required from the Government and NGOs (Non-Government Organizations) for the completion of the structure.

Table 1. Tentative estimation for the resilience (without reinforcement)

Name	Unit Size	Price(appx)	Quantity	Total
Paschati(support)	10’ each (Borak)	13 tk/ft	61	7930 tk
Roof	10’ each (Borak)	13 tk/ft	22 (avg)	2860 tk
Floor(21’X21’)	25’ each (Muli)	240 each	30 (avg)	7200 tk
Elevation(13’X7’)	25’ each (Muli)	240 each	18 (avg)	4320x4 tk
			Total	35270 tk

Table 2. Tentative estimation for the reinforcement (core structure)

Name	Unit	Price(appx)	Quantity	Total
Concrete Work	20 cft	4110 tk	09 nos	36990 tk
Steel H Beam	1 ft (7 kg appx)	150 tk/kg	252 ft	264600 tk
			Total	301590 tk

A subtotal of 35270 + miscellaneous =39000 tk is required for the reconstruction of the house after the storm and for resiliency. And an approximate funding of 301590 + miscellaneous = 332000 tk is required to make the steel core. The miscellaneous includes bolts, anticorrosive paint, ladder to access macha, other joinery etc. The footing and steel frame are considered to be safe with the high velocity of wind during the storm. Due to the high stiffness of the RCC substructure, the overall drift is zero in the FEA (Finite Element Analysis), but when the study of the single superstructure part was conducted, the value met the IBC (International Building Code) limit.

4 Calculation and Result

The findings from the literature review show that the proposed structure is based on stable structural material supplied by NGOs or other funding together with locally available materials that requires very little technical knowledge to build the structure. The structural considerations are such that, in the general situation of a flash flood, the bamboo structure will sustain, and in the extreme case, only the core will remain and the dwellers are moved to the cyclone shelters. The extreme case scenario is simulated in ETABS for structural analysis. The wind velocity of the extreme case is considered, 80 m/s (179 mph) with a pressure of .027 kip/feet^2 above 10 feet from the ground. The wind load is distributed in wind-ward, leeward, and sideward assigned with dead loads of the materials. According to BNBC 2020, occupancy type I, exposure type C, and live loads of inhabitants (5 people per dwelling) are also included.

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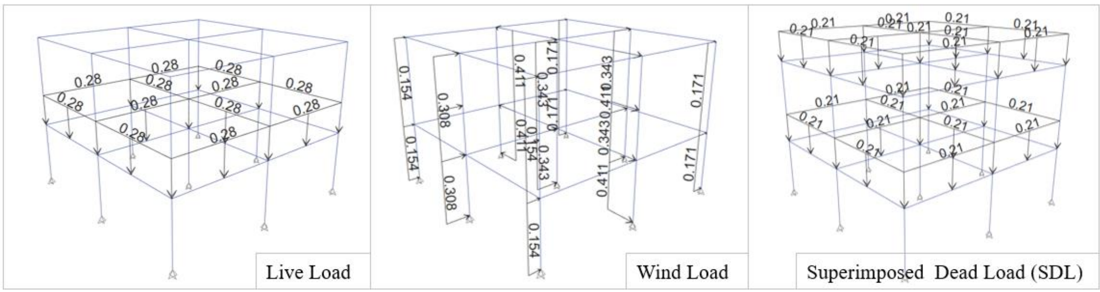

Fig. 7. Assigned load combinations to the core in ETABS

In extreme cases when the hazard is severe, and people are moved to the cyclone shelter, only the inner core will sustain and in the post-disaster period, the dwellers can manage to prepare the shelter with locally available bamboo to start again. The steel design performance is analyzed and falls between the ratios of 0.00 to 0.50.

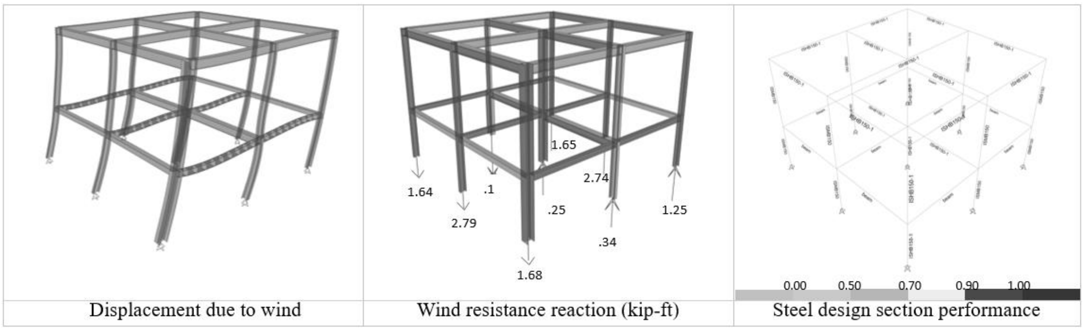

Fig. 8. Structural Analysis of the conceptual structural core

For withstanding the wind-uplifting force, we consider the resistance force of the columns on the windward side. The maximum force is 2.79 kip-ft. The self-weight of the footing with the short column is calculated to check the stability.

$$\text{Self-weight of footing} = \frac{\left(4 \text{ X } 4 \text{ X } \left(\frac{10}{12}\right)\right) \text{X } 150}{1000} = 2.00 \text{ kip-ft} \quad (1)$$

$$\text{Self-weight of short-column} = \frac{(1.5 \text{X } 1.5 \text{ X } 3) \text{X } 150}{1000} = 1.0125 \text{ kip-ft} \quad (2)$$

From Equations (1) and (2),

$$\text{Total Self-weight} = 2.00+1.0125 = 3.0125 \text{ kip-ft} \quad (3)$$

Here, the total self-weight of the footing with the short column is greater than the maximum wind reaction force at the windward columns. So, the core structure with withstand the wind force of a cyclone.

The scope of this paper is the incremental structure that can be more permanent and have a higher lifecycle and resilience that can be prepared with funding. The lack of a physical survey due to time constraints and COVID hazards and the gap between physical and realistic structural analysis of the proposed design are identified as the limitation of the paper.

5 Discussion and Conclusions

To ensure resilience from cyclones, two scenarios are considered. In general situations when a flash flood occurs, and wind pressure is within range, the bamboo structure will sustain, and to escape flooding, the dwellers can take shelter in the upper chamber above the ceiling. In the extreme case scenario, the bamboo elements are destroyed and only the steel shell structure will sustain, where the damaged portions can be rebuilt to make it habitable again.

It is impossible to overstate the hazards associated with the Rohingya issue and should be handled with the appropriate expertise. To ensure basic livability, the architects have a lot to do. A temporary post-disaster shelter that can be easily dismantled or even used permanently with incremental support for reinforcement, the proposed design will allow the community people to construct by themselves using locally available sustainable materials with minimal reinforcement provided by the authority or concerned NGOs.

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