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DEVELOPMENT OF SUSTAINABLE LOW-COST HOUSING IN BANGLADESH

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Abstract

Most people in low income areas of Bangladesh live in climate non-resilient houses. The research is directed towards reducing the sufferings of vulnerable population. This is possible by developing sustainable low-cost houses that can withstand natural hazards and cost effective. The research presents an overview of low cost housing building techniques and materials, study and research to improve the techniques and materials with laboratory test and numerical analysis. In the study, different types of mud-concrete like, cement was mixed with soil at different percentages for plinth, wind bracing and knot binder were tested to get better stiffness of the bamboo frame. Bamboo reinforced concrete slab was also analyzed, corrugated iron roof and wall were also tested as substitutes and comparative analysis. For testing, three different percentage of cement (3%, 4%, 5%) by weight was mixed with Dhaka and Dinajpur soil separately to prepare mud concrete. Considering test result on compressive strength & washing out particles (%) Dinajpur soil is more preferable for mud concrete. A numerical study of existing housing model and re-strengthening model are done by ETABS V9.6. The numerical study conducted on the braced model found that average deflection is 25.4 mm, which is reasonable for structural stability.

Keywords: *Low cost housing; plinth; stiffness; non-engineered housing; mud concrete.*

1 Introduction

1.1 Background of the Study

Bangladesh is among the most populous countries in the world. According to the latest census conducted by the BBS in 2022, 2.87 million people live in slums across the country. While most people migrate for economic reasons, more than 36% leave for the cities because of natural disasters, river erosion and recurrent flooding.

People build houses to live a happy and comfortable life. Safety and comfort are the basic essentials for housing. As Bangladesh is a low land deltaic country having 33% people lives on coastal zone of Bay of Bengal covering 19 districts, they are vulnerable to natural hazards like cyclone, flood, high wind etc. (Bimal K. Paul et al., 2010). Because of illiteracy and lack of idea of modern house, the people live in low income area build their house with locally available woodcraft, artesian, bamboo, tin and thatches for living somehow only. They do not have enough money to build a durable house. As a result, most houses in low income area as well as coastal areas are non-engineered. Most of them are temporary kuccha houses. The sufferings of the householders of these houses become considerable during flood or cyclone followed by tidal waves. Even heavy rain and high wind affect them almost every year.

1.2 Objectives of the Study

The primary objective of this study is to improve the durability, sustainability and cost reduction in building houses of rural and coastal areas. To obtain this objective special emphasis is given on:

i. Identification of low-cost sustainable housing construction techniques in the context of Bangladesh
ii. Development of durable base or plinth, improvement of the frame stiffness and finding suitable alternatives for roof and walls through laboratory test and numerical analysis.

2 Methodology

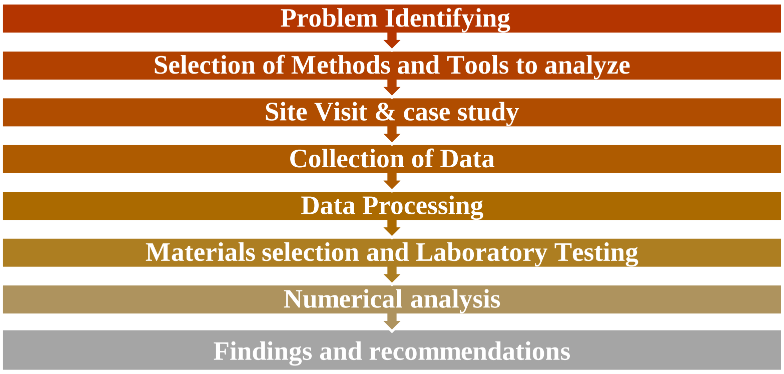


Figure 1. Methodological Framework of the study

2.1 Study Framework

The whole process is conducted through site visit, data collection, laboratory testing and numerical analysis.

a. Sustainability and cost effectivity are the two most important terms in this study. To maintain these two criteria relevant problems to be faced are- materials availability, stiffness, costing, installation system, energy consumption etc.
b. Data Collection (properties, availabilities, cost, construction procedures etc.) from House Building Research Institute (HBRI), National Housing Authority (NHA), Local Govt. Engineering Department (LGED), different site visits with cost effective materials supplier and construction company.
c. Data processing through software analysis, laboratory testing (Compaction, stiffness) etc.
d. Materials selection and laboratory testing depend on sustainability and cost effectivity. Sustainability of housing consists of improved plinth, stiffness of frame, light and impermeable roof and wall in a way that conserves resources, optimizes energy and water use and that will last longer with quality systems. They are efficient in terms of manufacturing, shipping and installing.

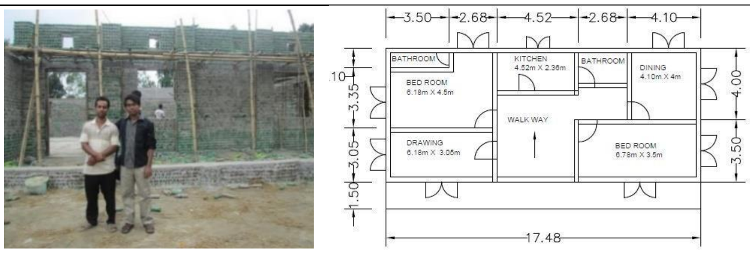
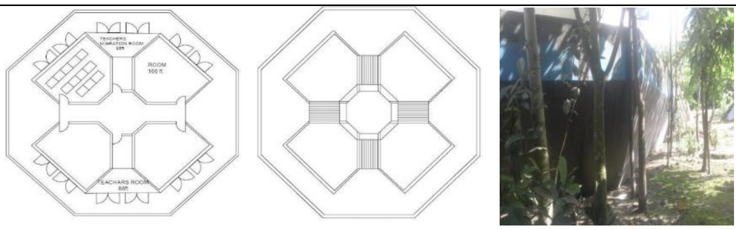
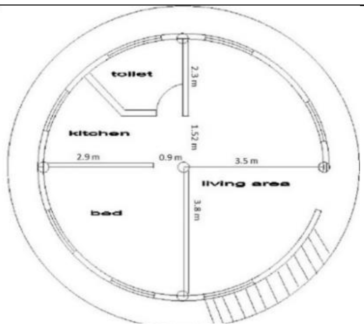
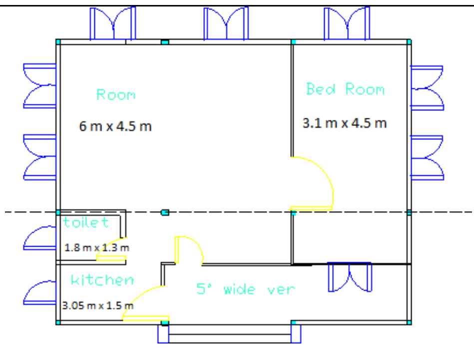
2.2 Materials survey

Visiting HBRI premises and laboratory, we find out many low cost construction materials. Some of those materials are shown below:

1. Sand-cement solid block Compressive strength: 30 Mpa Size: 240 x 175 x 70 mm Weight: 3.22 kg Water absorption: <10% 	2. Non-fired solidification Brick Compressive strength: 50 Mpa Size: 240 x 115 x 70 mm Weight: 2.9 kg Water absorption: <8% 
3. Interlocking compressed stabilized earth *block:* Compressive strength: 50 Mpa Size: 300 x 150 x 100 mm Weight: 7.5 kg Water absorption: <10% 	4.Compressed stabilized earth Block Compressive strength: 75 Mpa Size: 240 x 115 x 76 mm Weight: 3.95 kg Water absorption: <10% 
5. Structural Insulated Panel (SIP) Wall panel thickness: 114 to 165 mm. Roof panel thickness: 260 to 310 mm Largest panel size: 2.8 x 7.3 m. Compressive strength: 0.20 Mpa 	6. Reclaimed timber Mid-range of length: 1.8-2.4m. Up to 40 points harder on the Janka hardness scale than virgin wood 

2.3 Site visit and survey

We visited several low cost housing site. Bottle house at Lalmonirhat, Floating house of shariatpur and different projects situated in House Building Research Institute (HBRI) premises were among of them. A brief description are as follows:

Case Study	Plans and Image	Specific Information
Bottle House	 (i) (ii) Figure 2. (i) Author infront of Bottle House (ii) Plan view (dimension in metre)	Area: 158 sq-m. Site location: Nawdabash village, Kaliganj, Lalmonirhat Project costing: Around 5 lakhs. Materials: PET bottles (80000 pieces), fresh Sand, Cement, RCC (minor). Environment friendly, fire and heat resistant
Floating House (ZAHAZ BARI)	 (i) (ii) (iii) Figure 3. (i) Finished Floor Plan (ii) Roof Plan (iii) Basement of the Zahaz Bari	Area: 11.15 sq-m Site location: Majhirghat, zajira, Shariatpur Project duration: 3 years Materials: Rcc, Tin, Ferrocement, Floating for minimum 0.46 m height flood level, Built by HBRI as test case.
Stilt House Structure	 Figure 4. Floor Plan of Stilt House	Located at Kollynpur, HBRI area Total floor area: 52 sq-m
Reusable Prefabricated Model Houses	 Figure 5. Floor Plan of Reusable Prefabricated Model Houses	Total floor area: 58 sq-m. Situated at Shibaly Upazilla, Manikganj To increase affordability and acceptance of local people. The reusable prefabricated houses design consists of 10 m x10 m basic unit.

3 Improvement Techniques followed

3.1 Plinth or Base

During flood plinths made by mud can be washed away. Plinths of mud are often weak because there forms crack and the cracks allow water to enter and soften mud. Mud plinths can be strengthened by using chopped straw, rice husk and cement. The strength of mud concrete also depends on the percentages of cementing material and soil properties. Again with an increase in percentages of cement total cost will also increase. For a comparative study different percentage of cement is added to soil, say 3%, 4% and 5%. The soil for mud concrete was collected from two areas of Bangladesh, Dhaka and Dinajpur. The impurities like gravel or khoa were separated from the soil. Then the soil was dried at normal temperature. For testing, three different percentage of cement (3%, 4%, 5%) by weight was mixed with Dhaka and Dinajpur soil separately to prepare mud concrete. To ensure uniformity of cement it was mixed up vigorously in dry condition. Then water was added to mixer to get a desired consistency. This mixture is termed as mud concrete which is placed at 12”x12”x12” size wooden box. To get desired compaction standard proctor test was performed where mud concrete mixture was placed in 3 Layers each of 10.15 cm (4.0 in) height. Each layer was compacted by 25 blows with 2.5kg hammer. These specimens are prepared for 28 days and then dried at the normal heat, air and temperature. The dried mud concrete samples are then weighted first and freed from wooden box carefully. Then these samples are kept submerged into water. The condition of mud concrete samples is observed at an interval of 15 days. The compressive strength of each sample was measured from the cube strength. Hence, Details of mud concrete using Dinajpur soil and Dhaka soil are as follows:

Table 1. Details of mud concrete using Dinajpur soil

Sample No.	% of cement	Wt. of soil (kg)	Wt. of cement (kg)	Compressive strength (N/mm^2)	Washing out Particles (%)
1	3	105.10	3.15	27.24	87.25 (submerged for 06 months)
2	4	101.02	4.04	39.11	
3	5	72.49	3.62	50.91	

Table 2. Details of mud concrete using Dhaka soil

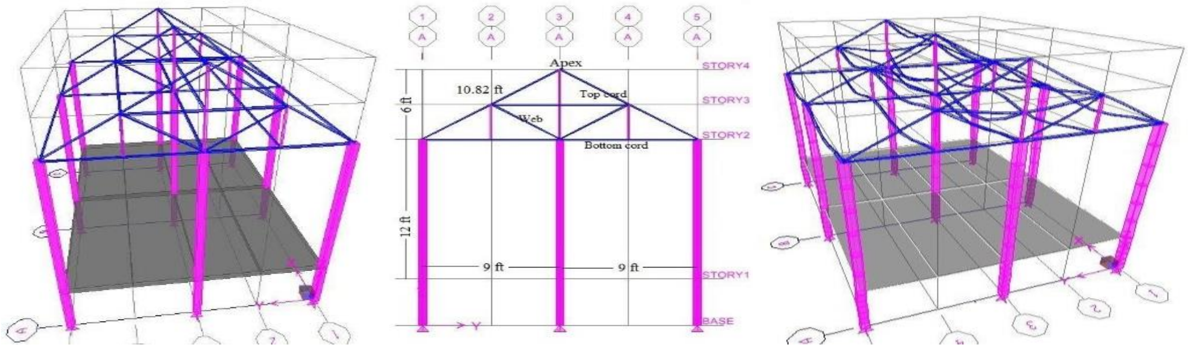
Sample No.	% of cement	Wt. of soil (kg)	Wt. of cement (kg)	Compressive strength N/mm^2	Washing out Particles (%)
1	3	67.13	2.01	19.32	91.3 (submerged for 02 months)
2	4	67.59	2.70	22.43	
3	5	68.95	3.45	31.76	

Dinajpur soil is more preferable for mud concrete comparing to Dhaka soil.

3.2 Frame

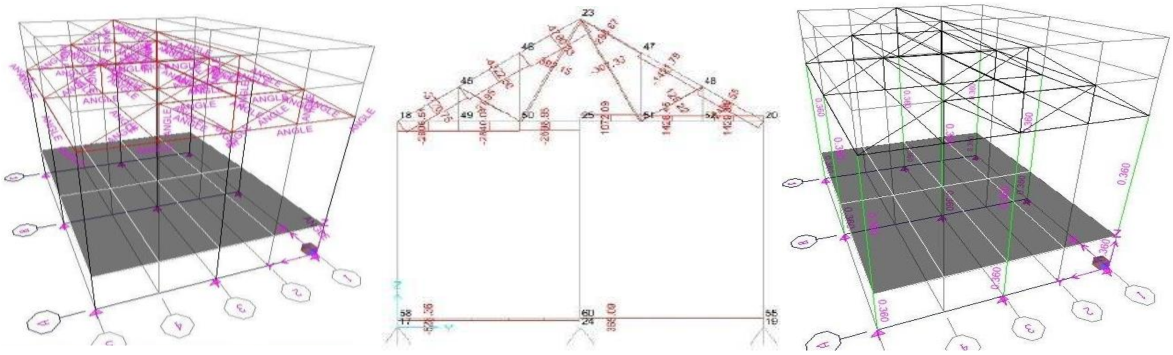
A numerical study of existing housing model and re-strengthening model are done by ETABS V9.6. In this analysis a house having plan 24 *18 feet are considered for investigation.

The house has elevation of roof level at 12 feet and total height of at roof tip is 18 feet. The inclination of roof is assumed to 33.69^0. Members for the house are considered as steel-concrete frame and the roof is Tin-cocksheet roofing composite. The RCC columns are 6*6 inch, Truss member 1.5*1.5 inch, Tin-cocksheet composite 2 inch is considered. The Young Modulus of Elasticity is 3600 ksi & 29000 ksi respectively for concrete and steel. The conventional structure as shown in Fig. 6(i) and 6(ii) is strengthening using tie and bracing. The vertical tie bracing is provided along parallel to wind direction which greatly reduce the lateral deflection of the house as shown in Fig. 6(iii) and 7(i). At the bottom chord level cross bracings are provided which increase the rotational rigidity of the house. The wind pressure coefficient on the structure is 0.90 & 0.60 along windward and leeward direction respectively is calculated according to UBC-94 with maximum wind speed 260 km/hr. The numerical study conducted on the braced model by ETABS V9.6 found that average deflection is 25.4 mm. The analyzed result shows that the member forces are also reduced due to application of tie and bracing. As a result, the possibility of joint failure that was occurred in unbraced house greatly reduce due to the application of tie and bracing. The Fig. 7(ii) shows the member force due to the application of tie and bracing with existing house. The analyzed result shows that there is a little variation of support reaction. The uplift and downward force acting on the support is followed as Fig. 7(iii).



(i) (ii) (iii)

Figure 6. (i) 3-D view of the model (ii) Elevation view (iii) Deformed shape of the model



(i) (ii) (iii)

Figure 7. (i) Steel design check (ii) Axial forces of the model (iii) Reaction

It's found that application of tie and bracing increase the stability of house against overturning or uplift under strong wind. To increase the stability of house against uplift square concrete block attached with bottom of column by steel cable may be used.

Again, it is found that due to application of tie and bracing the tensile force in most of the truss member has been reduced greatly. The reduction of member force causes stability against joint failure.

3.3 Wall

SANDWICH WALL panel is considered for exterior wall and COCONUT COIR BOARD panel is for interior wall. Per unit cost of interior wall is 450 Tk./sq-m and for exterior wall is 850 Tk/sq-m according to HBRI.

(i) (ii)

Figure 8. (i) SANDWICH Wall panel (ii) COCONUT COIR BOARD

3.4 Roof

Here we consider Tin-cocksheet composite for roof. This is a waterproof, lightweight component. This house will not be very hot due to cocksheet which acts as heat insulator. Per unit cost of Tin-cocksheet is 720 tk/sq.m according to HBRI. The detailing is given below:

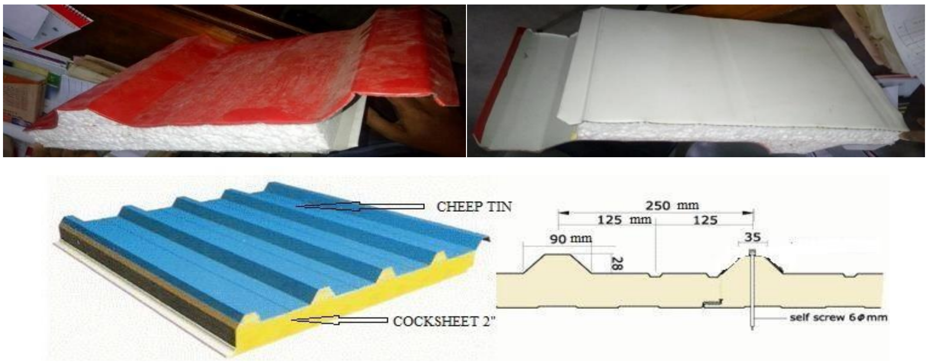


Figure 9. Tin-cocksheet composite with its detailed cross-section

4 Results and Discussions

From above investigation and survey we found that the cost of Reusable prefabricated house is 4,79,471 Taka and cost per square feet area = 768/- Where Our own model that we have performed costs 1,94,440 Taka and cost per square feet area = 450/- which reduced the costs about 40%. From the numerical study presented in this paper it is found that application of tie and bracing increase the load carrying capacity of the traditional houses. As the member force in roof truss are greatly reduced as the application of tie & bracing, it reduces the possibility of joint failure and blowing up of roof. The downward force on column indicate it stability against blowup. Again it's found that the deflection of the house is 25.4 mm. So it can be concluded that the use of tie and bracing, mud concrete coconut coir board panel, tin-cocksheet composite can be used as construction material for engineered housing measures for low income people which can be easily installed and moved away also during erosion.

5 Conclusion

This paper presents a brief overview on roofing, walls and other few components as of sustainable low cost housing, which can be modified to increase stability and more cost effective in future. Steel frame for low income area may be preferable than other technologies as the analysis. Dinajpur soil is much better than Dhaka soil for preparing mud concrete. But as future recommendations, performance of soil from other areas of Bangladesh maybe investigated. Again the minimum required thickness of mud concrete also can be investigated. The materials used for different projects have less environmental impact, so further research can be ensured to design eco-friendlier housing or green building.

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