EARTHQUAKE RESISTANT NON-ENGINEERED BUILDING CONSTRUCTION FOR RURAL AREA IN BANGLADESH

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ABSTRACT:
Bangladesh is extremely vulnerable to seismic activity. While the earthquake resistant building design and construction code has been developed in sophisticated national/city level, the implementation at the local level has been more of an exception than the rule. People used to make their houses by local materials and local construction technique without any engineering philosophy especially in rural areas. Therefore, there is an imminent need to know the actual physical condition of the rural houses and to estimate the risk associated with them, to bring into force simple, user friendly, non-engineered construction practices for use by the community and the construction artisans. A physical survey has been done on the existing condition of the rural housing. From this information the problems are identified with respect to earthquake resistant non-engineered housing technique. Techniques of strengthening of existing rural houses to make them earthquake resistant are elaborated and earthquake resistant building technology for new houses are formulated. These techniques may be the guidelines to the rural people for making low cost earthquake resistant house and also will make a pointer towards engineered building from non-engineered construction.

KEYWORDS:
Non-engineered construction, Earthquake risk assessment, Strengthening techniques

1.INTRODUCTION

Earthquakes are natural hazards under which disasters are mainly caused by damage or to collapse of buildings and other man-made structures. Earthquake damage depends on many parameters such as, intensity, vibration period and frequency of ground motion, geologic and soil condition, quality of construction etc. Non-engineered buildings are frequently affected by earthquakes and need special attention. According to Arya (1994), *"non-engineered buildings are defined as those that are spontaneously and informally constructed in various countries in the traditional manner without any or little intervention by the qualified architects and engineers in their design"*. Experiences from many past earthquakes, it has been observed that these buildings show poor performance during earthquake. The damage scenario of these types of rural houses due to Rangamati, Bangladesh Earthquake (2003) can be seen in figure 1. In view of the continued use of such buildings, it is essential to introduce earthquake resistance features in their construction (IAEE, 2004).


Mud House


Masonry


Masonry


RCC

Figure 1 Damages of Rural Non-Engineered Houses during 2003 Rangamati Earthquake

1.1 Non-engineered Construction in Bangladesh

In Bangladesh the majority percentage of people live in rural areas. Most of them are very poor. Due to financial problem most of the family built their dwelling house using low cost local materials and technique. For low quality building materials and low quality construction technique, the houses are not strong enough to resist the natural hazards. Construction and distribution pattern of housing in Bangladesh develops according to the need of the inhabitants under asset of geographic control and changes with the evolution of the human needs at the different stages of socio-economic and cultural development. The houses in rural area are generally made of indigenous building materials like bamboo, straw, grass, jute sticks, leaves, mud and corrugated iron sheet etc. Approximately for the last forty years brick has been using in the rural areas as the building material. The use of corrugated iron & bricks in the rural houses can be assumed as the influence from the urban areas as the durable and prestigious building material for shelters. Corrugated iron sheets, bamboo, straw, jute sticks or with the combination of mud are basically used for the construction of the enclosures. For the roofing, corrugated iron sheets and thatch are the most common in the rural areas. In some areas of the northern dry regions, clay tile roofing can be seen. In most of the areas of rural Bangladesh plinth of the rooms are constructed with rammed soil.

1.2 Types of Non-engineered Houses in Bangladesh

The characteristics of non-engineered rural houses can be recognized by its roofs and walls. These are subjects to change with the variations of locations, climate and availability of local materials and technologies. The following types of rural houses are taken into considerations for this seismic assessment study.

1.2.1. Mud walled House

In most of the rural areas of Bangladesh, rural houses are characterized by mud walled. Sometimes walls are made of sun dried earthen blocks of one to two feet thickness. These mud walled houses are generally oblong in shape and covered with the roofs made with clay tiles, thatch or corrugated iron sheets. The application of these construction materials depends on their availability and the ability of the house owners. In these specific regions the lands are normally above flood level. Besides this, relatively less rainfall, dry climate and lateritic soil (which gets very hard when dry) are the main reasons behind the mud constructions. Relatively taller (15′) mud walled houses are found in the southwest part of Bangladesh. The houses with two or three levels are common in Chittagong region.

1.2.2. Bamboo walled House

In the piedmont alluvial plains, specially in Rangpur, Moribund delta area in Jessore and Haor Basins, flood plains of the Ganges, the Jamuna , the Brhamaputra, the Meghna, the Tista and in some areas in eastern and northern regions, the walls are generally made of bamboo and rooms are configured in rectangular shape. Bamboo is used for making posts and enclosing elements, which is called ‘Bera’. Sometimes timber is used for the post and making an upper horizontal floor in the room. This horizontal floor is used for storage purposes. It also acts as a thermal buffer in hot and cold seasons. Sometimes the bamboo enclosures are plastered with mud to protect it from rain and for aesthetics purposes. The bamboo walls with corrugated iron sheet roofs are the common practice in the rural areas and around Chittagong, Dhaka, Pabna, Narayangang, and Chandpur districts, but they can also be found scattered in all of the flood plain regions.

1.2.3. Timber House

Relatively smaller groups of populations in Cox’s Bazar, Teknaf, and Moheskhali are using the house forms having walls constructed with timber. Generally, the houses are built on raised wooden platform to get safety from snakes and other animals. The lower parts of the houses are also used for various purposes like storage, keeping domestic animals, different family activities etc. Another motivation behind this wooden construction is the availability of wood in the forest areas. Some of these buildings are also finished with different wood

curving for aesthetics purposes. With these distinctive features, the houses are representing the special identity of those regions.

1.2.4. Timber and Brick built House

The timber and brick built houses are common in the east of Sylhet district. The floors, plinths and the lower parts of the walls are constructed with brick while the rest portions of the walls are constructed with bamboo reeds covered with cement or mud on the both sides. Posts are made with timber logs and roofing with corrugated iron sheet or thatch.

1.2.5. Corrugated iron (C.I.) Sheet built House

C.I. sheet was not being used as the indigenous building material in this region. Later on, for its durability, it becomes one of the major building materials in local tradition. In the northern part of Sylhet, it is very common to build houses (walls and roofs) with corrugated iron sheets. Heavy rainfall in that particular region is one the major reasons behind choosing the corrugated iron sheets. Corrugated iron sheets are providing protection against rain and dampness of the weather. Another reason of choosing the corrugated iron sheets is the influences from the buildings of tea gardens constructed in British colonial period. The economic ability of the peoples of that particular area is considered as an additional reason behind the selection of comparatively expensive building materials.

1.2.6. Thatch walled House

In the Haor basins and Chalanbill areas houses are characterized by thatch walls, where straw, long grass, jute sticks and thatch are available and cheap. These materials are also used for roofing purposes except jute sticks. The main reasons of selecting these materials are the cheaper price and the dismantle capability in the natural hazards like floods.

1.2.7. Masonry House

In Bangladesh, masonry houses are seen in almost every rural area, but in small quantity. This type of building is built with bricks. Here suitable foundation is provided with brick flat soiling. The creation of tensile and shearing stresses in walls is primary cause of different types of damages to such buildings.

1.2.8. Non-Engineered R.C.C. building

With the spread of reinforced concrete construction to urban and rural areas, often buildings are constructed using R.C. columns and beams without proper engineering design, based on the experience of local masons and petty contractors. In most cases, connection details are not in a proper manner, beams simply rest on the top of columns, isolated columns with long verandahs are used, which introduces deficiencies from seismic view point.

1.3 Socio-economic constraints in earthquake resistant building construction

There are a number of socioeconomic constraints which do not permit the adoption of high level of safety in the buildings and these are as follows:

- Lack of concern about seismic safety due to infrequent occurrence of earthquakes.
- Lack of awareness that buildings could be made earthquake resistant at small additional cost only, hence lack of motivation.
- Lack of financial resources for additional inputs for meeting earthquake resistance requirements in building construction.
- Other normal priorities on financial inputs in the daily life of the people.
- High cost of cement, steel as well as timber in Bangladesh, and

- Lack of skill in seismic design and construction techniques and unorganized nature of building construction.

Such considerations therefore compel the continued use of seismically unsuitable construction practices. While theoretically, if appropriate resources and building materials are made available, it may be possible to construct buildings which can withstand the effects of earthquake without any appreciable damage, but practically it is not feasible to do so due to very high cost involve (IAEE, 2004). The objectives of this study can be summarized as:

- To perform a physical survey on the non-engineered housing pattern on the basis of construction materials and construction technique used in the study area to know the as built physical condition of the rural houses.
- To identify the structural deficiencies of the existing non-engineered rural houses with respect to earthquake resisting housing technique.
- To formulate strengthening techniques of existing rural houses to make them earthquake resistant.
- To formulate a constructional methodology for earthquake resistant rural houses using local construction materials on the basis of engineering senses and possible economic consideration.
- To identify the cost effectiveness of different type of houses considering seismic issue.

2.STUDY AREA

Chitagong, the port city and the commercial capital of Bangladesh, stand in seismically prone area. The study area, Pahartoli Union under Raozan thana is situated in seismic Zone-2 with PGA as 0.15g. There are 13 schools, 2 colleges, 1 engineering university, 4 mosques and pagodas. The total population of this union is 18,354. Generally, the people of this union like to built mud house, bamboo house, masonry and non-engineered R.C.C. building. On an average 12.71% of the total population lives in non-engineered R.C.C. building, 18.83% live in masonry houses, 36.63% live in bamboo houses and 31.83% live in mud houses. Most of the people live in subhuman condition. They are doing irregular job such as day-laboring or sharecropping. They are living in congested and unhealthy dwellings, with no ventilation. Some of the people are related to the permanent jobs such as banker, teacher, shopkeepers etc. Overall economic status of the major portion of the population of this union is lower middle class and lower class. Location map of the Pahartoli Union is shown in Figure-2**.**

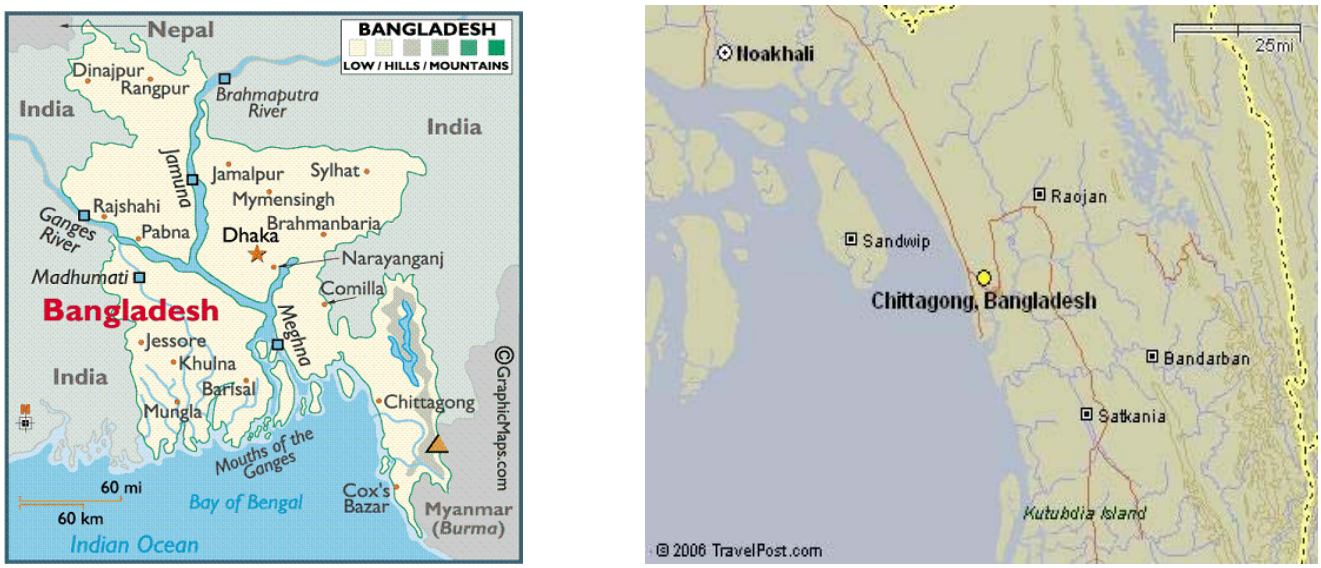


Figure 2 Location Map of Study Area

3.HOUSING & POPULATION DATA

From the physical survey over the existing houses of the study area based on the construction materials and techniques, the houses are divided into following four major types and are shown in Table 3.1. Peoples living in these dwellings have been also classified and are shown in Table 3.2.

Table 3.1 Number of House according to Types

Village	Types of House			
	Mud	Bamboo*	Masonry	Non-engineered R.C.C. building
Dewanpur	118	64	40	27
Khaikhali	71	153	40	37
Pahartoli	99	78	49	33
Unshattarpara	82	71	17	12
Housing Pattern				

Table 3.2 Number of Population for Different Types of House

Village	No of Population			
	Mud	Bamboo*	Masonry	Non-engineered R.C.C. building
Dewanpur	692	373	233	160
Khaikhali	124	765	155	126
Pahartoli	565	450	279	192
Unshattarpara	523	453	111	75

**Bamboo houses are not included in this study for analysis because of less vulnerability against earthquake.*

4.STRENGTHENING & NEW TECHNIQUES WITH COST ESTIMATION

It is not possible to rebuild thousands of existing houses to make them earthquake resistant. So it is become inevitable to formulate techniques to improve the seismic performance of such type of existing houses.

4.1 Mud House

In present days mainly low income rural people are using this type of construction technique. The primary material used in this type of construction is mud. The mud used here is the mixture of clayey soil, straw, cow dung and coarse sand. From the experience of many past earthquakes occurs; it is proved that mud houses are more vulnerable to earthquake than any other type of traditional house, because of its brittle nature and lack of lateral force resisting system.

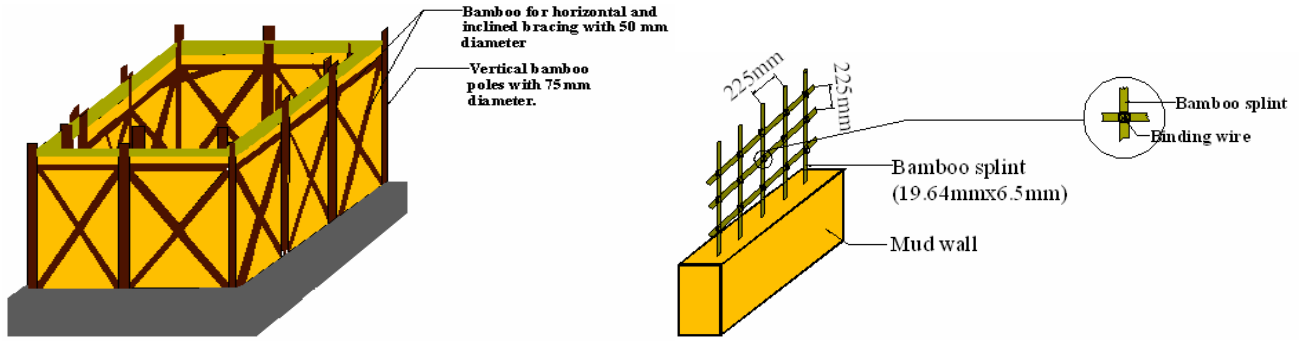
For the improvement of mud house one can use wooden bracing at the corner location of the beams, metal straps at connection location. Also shifting of roof truss at proper location, blocking of excess opening, use of cement plaster over walls, insertion of new walls are some of important measure to improve a mud house. Other than that insertion of bamboo poles at inner and outer side of the walls can be used. A concrete plinth used to fix the bamboos at ground level. Then some holes are made within the walls to connect the bamboo poles at inner and outer side of the walls using bamboo splints and wire**.** The horizontal bracings are provided between bamboo poles to reduce deflection. At the top of the wall these bamboo poles would be connected using the half bamboo splints in truss pattern. This make the whole house act as a rigid box against earthquake.

Mud houses are more vulnerable to earthquake. Even at low intensity considerable damages observed in this type of house. To reduce the effect of water cement stabilized soil can be used. Proper foundation should be provided and the foundation is preferably being constructed using brick with cement mortar. Use of cement

mortar plaster at the plinth level also reduces the effect of water over the building. Vertical reinforcement in form of bamboo mesh or post, provision of horizontal band over the wall use to resist lateral load over the building. If roof beams needed to be provided over opening, then reinforced lintel should be provided. The strengthening technique of existing mud house and new technique for mud house construction is shown in Figure 4.1. The cost effective measures for strengthened and new construction needed for seismic performance improvement of mud house is shown in Table 4.1.

Table 4.1 Cost Effective Analysis for Mud House

	Single Storey with C.I. sheet roof			Single Storey with Tile roof			Double Storey with C.I. sheet roof		
	Existing	Improved	New Earthquake Resistant	Existing	Improved	New Earthquake Resistant	Existing	Improved	New Earthquake Resistant
Construction	Traditional	Technical	Engineered	Traditional	Technical	Engineered	Traditional	Technical	Engineered
Strengthening	required	done	not required	required	done	not required	required	done	not required
Durability	low	moderate	high	low	moderate	high	low	moderate	high
Cost per sqm	$27.26	$28.91	$36.00	$19.63	$36.37	$42.63	$37.00	$43.20	$54.24



(a) **(b)**

Figure 4.1 (a) Strengthening of Existing Mud House (b) Techniques for New Mud House

4.2 Masonry House

Generally buildings of fired brick, solid concrete block, mortar blocks or stone are termed as masonry buildings. In this type of construction no reinforcing materials are provided to resist tensile force developed due to different types of lateral load (e.g. Cyclone, earthquake etc.) coming on the structure. In Bangladesh, typically brick masonry houses are found in both rural and urban areas. An increasing demand is observed in rural areas due to its durability than other types of traditional houses.

Improvements of mud houses are required to increase seismic performance. Insertion of new vertical and inclined members into truss, use of L-clamps, rectangular metal straps at connection locations of truss members and roof beams, cross bracings between purling, blocking of excessive openings use to improve masonry house. In addition to this, vertical Ferro Cement strap on most walls from bottom to top, especially on either side of the windows can be used. The Ferro Cement elements and the vertical rods would be anchored to the walls with the help of studs installed in the holes. To minimize the damage due to differential settlement of the foundation, reinforced concrete strips can be used attached to the existing foundation part of the building.

In the typical masonry building design, no reinforcing material is present to make the building sufficient strong against earthquake. Various experiments shows that, the modulus of rupture of bamboo is approximately one-third of high strength steel and the bond strength of bamboo in mortar is well enough to use it as a reinforcing material in masonry, especially in rural areas of Bangladesh. Because the masonry houses built are generally one or two storied and the bamboo can easily be used as a reinforcing member for them. Use of bamboo will make the construction cost within the limit of rural people. The strengthening technique of existing masonry house is shown in Figure 4.2. The cost effective measures for strengthened and new construction needed for seismic performance improvement of masonry house is shown in Table 4.2.

Table 4.2 Cost Effective Analysis for Masonry House

	Existing	Improved	New Earthquake Resistant
Construction	Traditional	Technical	Engineered
Durability	low	moderate	high
Strengthening	required	done	not required
Cost per sqm	$68.26	$81.30	$92.00

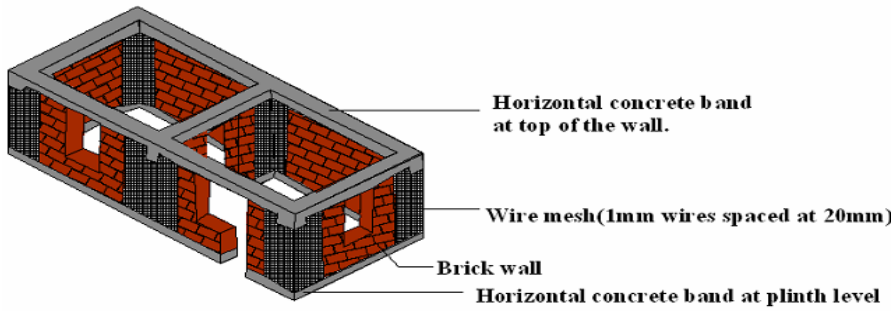


Figure 4.2 Strengthening Techniques of Existing Masonry House

4.3 Non-Engineered R.C.C. Building

In the recent days, RCC building is also popular in rural and semi-urban areas for their better strength and durability. Often these buildings are constructed in rural areas by the local constructor without any engineering design. No measure has been taken in the construction process to resist the lateral load and the connection details.

Improvement of non-engineered RCC building can be made by jacketing the existing beams and columns with additional concrete ring and caging of reinforcement, removing cover of the old steel, new steel can be welded with the old one thus by covering it again inadequate section of RC column and beam can be strengthened.

The reinforced cement concrete is one of the well known, durable and mostly acceptable building material. Even though due to lack of proper construction knowledge they show poor performance during seismic vibration. Appropriate design and careful construction procedure will be enough for make them earthquake resistant. The strengthening technique of existing non-engineered RCC building construction is shown in Figure 4.3. The cost effective measures for strengthening of existing RCC buildings and new RCC engineered construction needed for seismic design provisions is shown in Table 4.3.

Table 4.3 Cost Effective Analysis for Non-Engineered R.C.C. Building

	Existing	Improved	New Earthquake Resistant
Construction	Traditional	Technical	Engineered
Durability	low	moderate	high
Strengthening	required	done	not required
Cost per sqm	$110.47	$120.96	$140.86

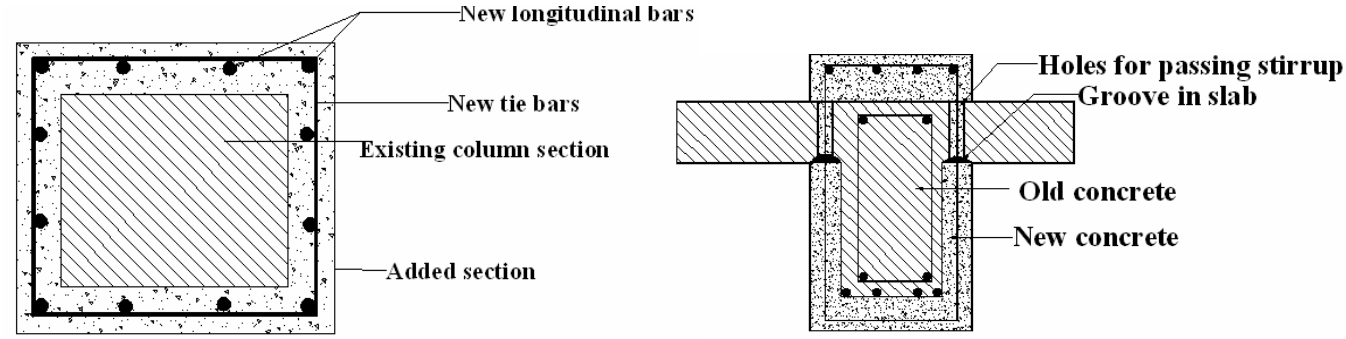


Figure 4.3 Strengthening Techniques for Existing Non-Engineered RCC Buildings

5. CONCLUSIONS

From the physical survey and the analytical study of housing scenario of the study area the following conclusion can be drawn:

- The physical survey shows that 12.71% of the total population lives in R.C.C. building, 18.83% live in masonry building, 36.63% live in bamboo house and 31.83% live in mud house.
- All the houses are made by locally available construction material and local construction technique without any engineering philosophy for lack of sufficient knowledge about earthquake risk
- The structural deficiency of the existing houses has been identified. The cost effective analysis of all types of house patterns has been evaluated as per Bangladesh National Building Code-1993.
- Strengthening technique of all types of existing houses has been formulated based on the locally available construction materials and construction technique by engineering science to make the rural house earthquake resistant. The cost of strengthening has also been evaluated.
- For each category of the house pattern the technique of construction of a new earthquake resistant house has also been formulated and the cost associated with the improved construction has been evaluated.
- Guide lines for construction of each type of rural house have been formulated, which can be used in practice.

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