Mud in Urban Context: A Study on Rammed Earth as Building Material in Dhaka City

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ABSTRACT
Traditional mud houses are integral part of Bangladeshi culture from the ancient period. But with the course of time urbanization, industrialization & technology have achieved an infinite development & people began to forget their origin-mud or earth. At present that time has come to rethink the existence-relationship with earth. Architects have started realizing the destructive effects of different building materials like concrete, C.I. sheet, etc. They are going back to nature with the slogan of ‘Go Green’. Recently mud is being used in urban areas even in capital Dhaka not only by poor masses but also in rich people’s residences, resorts, café and shops; sometimes in the form of fusion as rammed earth construction, sometimes as interior cladding or plastering material & sometimes for research. Sometimes mud is being used realizing it as an eco friendly material & sometimes it is being used only for aesthetical purpose. But for benefit & sustainability, every building material should be chosen after understanding its environmental & economic issues which can enhance a new horizon in construction arena being a true friend of nature & culture & create a revolution. This paper reviews and argues the environmental (temperature, relative humidity, carbon-dioxide emission, other climatic effects) & economic benefits (manufacturing & maintenance cost) of using rammed earth as a building material for urban construction in Bangladesh in context of Dhaka. A critical literature review & field survey using experimental & qualitative approach was adopted in this paper to investigate whether rammed earth construction & mud plastering is feasible in Dhaka compared to the conventional brick construction.

Key words: climatic-effects, cost, feasibility, rammed earth, urban.

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INTRODUCTION

Approximately half of people of the world live in earthen house because its availability and permanent solution in cheaper cost. The construction technique of earthen house is derived by the craftsmen by themselves so it is simple to build for the users. In Bangladesh still most of the people live in earthen house. Earth structures are found almost every area in our country with different construction technique and style, for example the Rajshahi region double storied mud house are found but at Jessore region single storied mud house are mostly found. The planning of these houses are also different from each other. In some region house made with mud cube mixed with rice husk another part of the country wall construct with direct layer of clay. These entire houses are climate responsive and mostly acceptable to the society. Regarding the traditional mud construction lots of study has done. Rammed earth is an ancient or traditional construction technique used in many countries of the world. The most common technique of the rammed earth construction is pouring and ramming Soil within the form work which is similar to modern concrete. At present rammed earth construction & mud plastering is being used in Dhaka for research works, low cost construction, residential & recreational purposes both for construction & interior design breaking the tradition of conventional brick buildings. The objective of this paper is to find out whether urban mud architecture’s rammed earth Construction is feasible in context of Dhaka using critical literature review & field survey with experimental & qualitative approach.

RELATED LITERATURE

Rammed earth is a method of building walls whereby a mixture of earth is compacted in layers between forms. Each layer of earth is approximately 15 cm deep. As each form is filled, another form is placed above it, and the process begins again. This is continued until the desired wall height is achieved (HBRI report, 2009). Forms can be stripped off as soon as the form above is begun, as the compressed earth wall is self-supporting immediately. The clay and moisture content of rammed earth is relatively low compared to that used for mud brick or other earth building methods. A wider range of soils are suitable when a small amount of cement is added to the mix. The result, known as stabilized rammed earth, is a strong masonry product which provides excellent thermal mass. Ordinary mud construction is popular in Bangladesh but the there is no significant rammed earth structure in this country.

According to Climate Classification, Bangladesh may be placed in a zone called Composite or Monsoon’ climatic zone, These climates usually occur in large land masses near the tropics of Cancer and Capricorn, which are sufficiently far from the equator to experience marked seasonal variations in solar radiation and wind direction (Atkinson, 1953). These climates are normally said to have two distinct seasons, a hot-dry and a warm-humid season, and often a third, best described as cool-dry. In different seasons average air temperature, relative humidity & other climatic variables change determines people’s comfort range. In Dhaka carbon-dioxide emission level & energy consumption is also very high. Stabilized earth construction is environmentally sustainable compare to conventional (fried brick, concrete, etc.) building materials & would be appropriate in the case of urban building construction in Bangladesh. Promotion & implementation of earth as an alternative urban construction material is worthwhile & significantly helpful in achieving environmental sustainability (Zami & Lee, 2009). Earth buildings have inspired many who are searching for ways of living that are in harmony with the environment & enable what Heidegger (1954) called ‘poetic dwelling’ (Dayaratne, 2003). In Dhaka Building material is available but expensive in comparison with living cost. Therefore, rammed earth may work as a sustainable building material for Dhaka. However, replacing traditional buildings with modern ones does not necessarily lead to progress. While recognition of the building
traditions is necessary it should be consistent with improvement techniques that address problems. In that way it will be possible to build & preserve a culturally suitable, regional, rural earth architecture which will be contemporary & durable as well (Ahmed, I.1994). To explore and transform the rammed earth construction technique in urban areas it is important to find out its feasibility & sustainability not only in environmental & economic context or as a fusion of traditional mud structure but in a holistic manner.

**Methodology**

**Step 1: Soil map analysis:** Soil map is studied to know the soil quality of which areas of Dhaka is suitable for rammed earth construction. Clay soil with plastic quality is the most suitable for the rammed earth construction.

**Step 2: Sampling:** Among the suitable areas two buildings are chosen in Housing & building research institute (HBRI), Dhaka in Darus salaam road which have concrete plain roof, plinth, almost similar surroundings, orientation & architectural features like opening, shading, interior-exterior relationship but have facades of different material of rammed earth & exposed brick. For interior mud plastering another building is chosen in Dhanmondi at Dhaka Art Center named Café Ajo.

**Step 3: Instrumental survey:** For physical dimensions an instrumental survey is carried out to know length, breadth (thickness) and height of each façade with opening areas using measuring tape.

**Step 4: instrumental survey with treatment-experimental approach:** Indoor-outdoor air temperature & relative humidity level is measured with thermo hygro meter (air temperature & relative humidity measuring device) using treatment keeping the openings close & open & convenient time sampling at noon & evening period in two days & measured at 1m high from ground floor level almost at the middle of the room. Table 1 shows instrument specification.

**Step 5: market survey & literature review:** Market survey & literature review is done to know energy consumption, carbon di oxide emission & manufacturing, maintenance cost.

**Step 6: observation & questionnaire survey-open ended:** Observation & open ended questionnaire survey is done to find out other advantage, disadvantage & climatic effects.

Table 1: instrument specification

<table>
<thead>
<tr>
<th>Brand name</th>
<th>KTJ-max-m in thermo hygro clock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model no.</td>
<td>TA218B</td>
</tr>
<tr>
<td>Origin</td>
<td>China</td>
</tr>
</tbody>
</table>

Fig. 1: conceptual framework of the study
**ANALYSIS**

**Soil quality**

Fig. 3 shows in Dhaka earthen construction is only 15 to 20 percent. The red clay soil found in Pubail, Uttara, Mirpur, Azimpur area is suitable for earthen construction most of the areas have become urbanized the new growing areas where yellow, grey & red mud found is suitable for rammed earth construction.

Fig. 3: earthen construction in Bangladesh
PHYSICAL FEATURES

Building location, orientation & outdoor features (surroundings)
Proper building orientation is one of the features rightly emphasized from the early stages of design. The most coveted orientation for Dhaka, i.e. north-south, is impossible for a given site, because of the site's geometry and orientation. Fig. 10 shows both the building are a little inclined with north-south orientation with dense green areas & water body, on the west & meadow on the north east corner as site force.
Indoor features
Both the building has no occupancy during survey with earthen furniture in rammed earth building & conventional wooden furniture in brick building. Fig. 12 shows some earthen furniture at HBRI.

Material
Fig. 11 & 13(b) shows rammed earth wall is layered (500 mm to 700mm) in which red soil gravel & brick chips can be seen. Fig. 13(a) shows the conventional building is built with first class exposed brick of 250mm thick wall.
Window opening, orientation & shading

In a recent study window orientation for buildings in Dhaka was studied aiming to exclude solar radiation during the hot periods of the day. It is a known fact that southern and western walls of a building receive huge amounts of solar radiation during the course of each day in our hemisphere. When these walls are pierced by windows, direct radiation from the sun penetrates into the indoor areas, thus creating an even greater source of heat (Ahmed, Z.N., 1982).

When a window is provided with shading, the shaded part of the window receives no direct radiation, though it continues to receive its share of diffuse radiation from the sky. In both of the cases studied window is provided in all facades with large cornice. Table 2 shows window area & Fig. 4, 5, 6, 7, 8, 9 shows facades of the both buildings. In both cases indoor air temperature would be controlled not only by openings but also by the dense foliage of trees.

<table>
<thead>
<tr>
<th>Case study(survey)</th>
<th>opening area in different façade(sq.m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>north</td>
</tr>
<tr>
<td>HBRI rammed earth building</td>
<td>1.17</td>
</tr>
<tr>
<td>HBRI Brick building</td>
<td>1.15</td>
</tr>
</tbody>
</table>

Table 2: opening area in case study buildings

Air Temperature & Relative Humidity

Thermal comfort is strongly related to the thermal balance of the body and this balance is influenced by environmental parameters like air temperature (Ta), mean radiant temperature (T), relative air velocity (v), and relative humidity (RH) (ASHRAE Standards, 1974). Air temperature determines the convective heat dissipation, together with any air movement. Humidity of the air also affects evaporation rate as moisture content of the air is related to wetness of skin, which in turns affect comfort sensation. (Mallick, 1996)

For Dhaka, the indoor air temperature for comfort with no air movement are within the range of 24 °C and 32 °C and relative humidity range is 50% to 95%. The mean comfort temperature for this range is 28.9 °C for air velocity up to 0.15 m/s. For higher velocities of 0.3 m/s to 0.45 m/s the upper and lower limits of comfort temperature increase between 2-3 °K and mean comfort temperature increases to 31.2 °C. (Mallick, 1996)

Table 3 shows, both rammed earthen & brick building helps to keep indoor temperature lower than outdoor either with or without air movement during hot sunny days & keep indoor temperature comfortable. Here indoor air temperature is a little bit high than comfort level but lower than outdoor. According to Fig.14 in case of both treatments rammed earth is much more effective than brick wall. For mud plaster the difference is very low & it works almost as exposed brick façade in respect of indoor – outdoor temperature variation. During cool evening period rammed earth also shows much effectiveness than others. It helps to keep indoor temperature higher & near comfort range than brick façade or mud plastered wall.
Table 3: survey data of air temperature & relative humidity with treatment at rammed earthen, exposed brick building & mud plastered on brick wall

Fig.15 shows, for relative humidity level all the material keeps indoor humidity level lower than outdoor in case of both treatment during both cool evening & sunny days. But rammed earth is much effective than brick façade. Mud plastered façade’s relative humidity variance between indoor & outdoor is lower than others. Humidity depends much on air movement & outdoor air humidity content. In this site outdoor humidity level is naturally high for the presence of water body & dense trees. However, in all cases the indoor humidity level increased in open condition of doors & windows.
LIMITATION OF THE STUDY

Lacking of air velocity data minimizes the analysis. Otherwise more detail analysis can be possible.

ENERGY CONSUMPTION & CARBON-DI-OXIDE EMISSION

Air pollution is one of the major environmental problems nowadays, especially for developing countries such as Bangladesh and brickfields have been identified as a vital pollutant source of the major cities of the country. Numerous brick-making kilns operating in the dry season are one of the major sources of air pollution in cities and a significant factor is that brick kilns are usually clustered near big sites in different parts of Bangladesh (Ahmed & Hossain, 2008). However, manufacturing of bricks is a burning question for air pollution in Dhaka. Some studies have shown that, in the Indian context, building a square meter of masonry with stabilized earth block consumes energy 15 times less than country fired bricks (Maini, 2005). Table 4 shows rammed earth construction is more eco-friendly than fired bricks and their manufacture consumes less energy and pollute less than fired bricks.

Total façade area without opening = [(length × breadth × total no. of façade) - total opening area] = [(2.4 × 4.7 × 4) - 7.57] = 37.55 sqm.

For country fired brick,
- energy consumption = 1657 × 37.55 = 62220.35 MJ
- [energy/consumption/sqm. = 1657 MJ] (Maini, 2005)
- Carbon di oxide emission = 126 × 37.55 = 4731.3 kg
- [Carbon di oxide emission/sqm. = 126 kg] (Maini, 2005)

Table 4: calculation of energy consumption & Carbon di oxide emission of Rammed earth building (HBRI), if brick used in place of mud

MANUFACTURING AND MAINTENANCE COST

Prime material of rammed earth construction is earth. It is available in site. There is no need to buy mud for construction which lessens the manufacturing material cost largely. However, rammed earth construction need 90% of its cost for shuttering & polishing as maintenance material. In case of plastering it is cheaper than cement but the difference is not so high. Table 5 shows a comparison of manufacturing & maintenance cost of rammed earth construction & mud plastering with conventional exposed brick wall & cement plaster.
Table 5: comparison of manufacturing & maintenance cost of rammed earth construction & mud plastering with conventional exposed brick wall & cement plaster.

Others: From observation & questionnaire survey some merits & demerits of rammed earth construction are found, such as:

Demerits
- Crack
- Erosion at rainy days

Merits
- Noise reduction
- Less construction time
- Strong & durable
- Recyclable

Discussion and Conclusion

From analysis it can be stated that for availability of material rammed earth is suitable only in the growing new areas of Dhaka. It keeps indoor air temperature & humidity level near comfort range than brick though mud plaster is not much effective in this regard. As rammed earth construction’s main material is mud & needs no environment hazardous processing or causes no pollution even for transportation & consumes less energy, it can be an alternative of brick. If the maintenance cost can be afforded at primary level (almost two years according to HBRI) it is beneficial in the long run for its longevity. However, if compared with land value of Dhaka it is not feasible for height restriction & thickness of wall. Even rainy season makes the structure vulnerable causing erosion & scorching dry summer causes crack. Therefore, using layers & textured shuttering a traditional pleasing look can be achieved which is architecturally pleasing.

In a nutshell it can be said that Rammed earth in context of Dhaka is comfortable according to air temperature & humidity level. It also reduces air pollution. Dhaka’s soil quality according to area basis its construction is possible & its architecturally gives a traditional look. But for crack, erosion, height restriction, comparison with land value results it can be used as building material only for special causes where green architecture is the primary & dominating issue.
REFERENCES

House & building research institute(HBRI) report, Hands on Workshop on modern structure & architecture(rammed earth construction), 2009
Schedule of rates, Public Works Department, 2008
Zami, M.S. & Lee, A. (2009), Reducing carbon dioxide emission by the adoption of contemporary earth construction in urban Bangladesh, Protibesh, Vol.13, Issue 2, pp 25-33.BUET.