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Towards Sustainable Rural Development: an Investigation on Clay based Materials, their Appropriateness and Potential.

Fatema Meher Khan
Lecturer, Department of Architecture
Bangladesh University of Engineering and Technology (BUET), Dhaka.
E-mail: fmkhan@arch.buet.ac.bd

Saimum Kabir
Lecturer, Department of Architecture
American International University Bangladesh (AIUB), Dhaka.
E-mail: saimum@aiub.edu

Shajjad Hossain
Lecturer, Department of Architecture
BRAC University, Dhaka.
E-mail: mshajjad@bracuniversity.ac.bd

Abstract
Building material always plays an important role in the generation of form and character in architecture, which varies from region to region depending on locally available material. In this climatic domain, mud houses are typical and hold an important part of our traditional shelter. Being a delta, the land of Bangladesh is a renewable source for raw material of clay[i] based products like mud wall and clay tiles. These materials also linked to the roots to the culture and philosophy of the rural people. Due to the advent of the industrially produced and imported building materials, like CI sheet, these traditional building materials have almost disappeared in different areas of Bangladesh. Research and conservation are needed to ensure that the country does not loose the benefit of traditional construction, materials and systems in the course of enduring modernization. Some recent attempts of constructing buildings with clay in order to achieve a sustainable development by utilizing local technique and local resources gives us an opportunity to rethink the issue more seriously. This paper reviews the traditional materials - the mud wall and clay roof tiles, their potential use and technical aspects. The objective of the paper is basically a reappraisal of indigenous building material in architecture of Bangladesh in order to finding a way to reestablish the traditional building materials, specially mud wall and clay roof tiles, in the context. Through the investigation, it is found out that like other materials these traditional building materials would prove as potential building materials in our contemporary vernacular architecture and thus once popular material - mud wall and clay roof tiles - could be revived in more innovative ways as a sustainable building material.

Key words: Indigenous Material, Sustainable Development, Mud Construction, Clay Roof Tiles, Local Technique, Low- cost.

1.0 Introduction

In the present context of climate change, energy crisis and global economic recession, planning for sustainable future is becoming a world-wide concern. In Bangladesh, where the severe impact of climate change is inevitable and energy crisis reaches at its peak during the last few years, it is necessary to develop appropriate strategies for sustainable future. According to the World Commission on Environment and Development the term 'Sustainability' refers to meet the needs of the present without compromising the ability of future generations to meet their own needs. The definition expresses a generalized concept of sustainability which has actually three different dimensions i.e. environmental, social and economical. In order to get a sustainable solution it is necessary to integrate these three different dimensions while creating a balance between the need and available resources. But the supply of non renewable resources (oil, gas, coal) is limited. So emphasis should be laid over renewable natural resources considering its availability and use. Since the rural areas are the major repository for our natural resources providing food and raw materials for shelter, the priority should be given to the sustainable use of these resources. In this regard, towards sustainable rural developments, local building materials like mud wall and clay roofing tiles can play a vital role.

Sustainable rural development is largely associated with the sustainability in rural architecture. The rural architecture of Bangladesh has distinct characteristics regarding of planning, use of materials and location. For centuries, rural

architecture has been using locally available natural building materials. It is only from the late nineteenth century that rural architecture began to change both structurally and in the use of housing materials. (Banglapedia, 2003). The traditional and more natural building materials are now gradually being replaced by factory made, imported building materials like CI sheet, cement, steel, plastics etc. that are often liable for the degradation of the quality of built environment, limiting the use of local technology and manpower and thus influence the rural environment and economy. These universal materials are often insensitive to culture, customs and values of the rural society. Again the productions of these materials are more energy intensive and also responsible for the emission of green house gases. Here the paper delineates the pros and cons of local building material with special emphasis on mud and clay based products and their use in rural architecture. The paper also tries to outline the strategies and the traditional and technical means of improving the scenario with an aim to get a sustainable solution. However this sustainability is essentially context specific which encompasses environmental as well as socio economic sustainability.

The main objective of the study is the reappraisal of indigenous building materials. The paper tries to study traditional building materials specially mud and clay based products. It also tries to identify the reason behind its failure and to find out its potential use. In addition, it also aims to give a direction for the development of local building material industry by utilizing local resources and techniques. The scope of the paper is limited in exploring the present condition, technical problems and giving direction to solve the problem.

A reconnaissance survey with photographic and observational study was undertaken to know present condition and the use of mud and clay based materials. Field survey in different areas of Gazipur, Dinazpur and Shatkhira etc. regions of Bangladesh was conducted in 2006. Available relevant literature has also been reviewed. Unstructured interviews have been conducted on local experts and users for having a clear perception of character, maintenance and preservation of mud structures and clay tiles.

2.0 An overview on rural housing and building materials

About 76% people of Bangladesh live in rural settlements and 77% of dwelling units are located in rural areas (BBS, 2003). A large portion of rural housing is still dependent on locally - available building materials. For instance, in Bangladesh out of 14.8 million households, 3.7 million (or about 25%) used bricks (fired and unfired) as wall material, while 9.4 million (or about 63%) used bamboo and natural fibers such as straw, jute sticks, etc. (SDC/SKAT,1991). A survey conducted by World Bank (1998) shows that about 52% of roofs of rural houses are built of natural materials which include thatch, leaf etc.

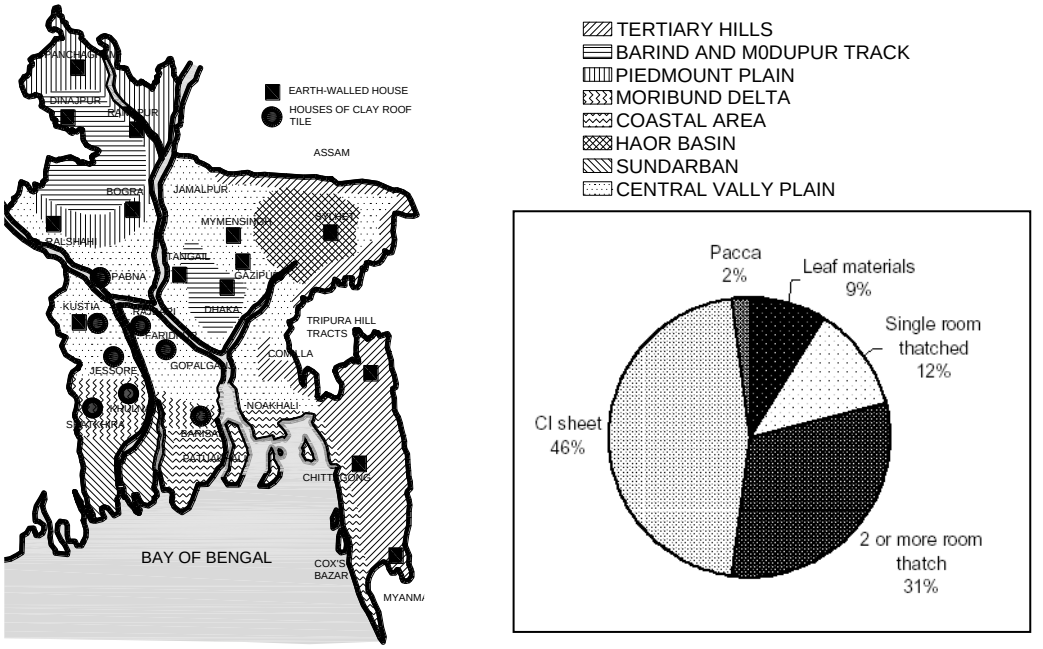

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Figure 01: Map of Bangladesh showing different areas where mud construction and clay roof tiles are used as chief building material. (Source : Field work data adapted with the map of Banglapedia, 2003)

Figure 02: Roofing material used in Bangladesh (World Bank-BCAS, 1998)

Unfortunately these traditional and more natural building materials are now gradually being replaced by the materials with high embodied energy like steel, plastic, concrete etc which are more dependent on high technology. Again in terms of environmental performance these materials often perform poorer than many other local building materials like mud and clay based materials. Besides the production of C.I sheet, brick, cement, plastic etc is more energy intensive and quite expensive. For example, the energy required for producing brick and CI sheet is much higher than mud block and clay roof tiles. The brick industries in Bangladesh consume high level of energy and are accountable for consuming 25.6% of Bangladesh's natural resources (Miah and Alam, 2002). The production process of brick and CI sheet is also often associated with air pollution (FAO, 1993). Again the thermal disadvantages of CI sheet is a serious problem especially in a hot humid climate like Bangladesh as CI sheet heat up very fast. (Ahmed, 1994).

On the other hand the traditional materials like mud wall and fired clay tiles have great potentiality in this regard. They are more environment friendly and energy efficient. The thermal performance of mud wall and clay roof tiles are quiet acceptable. The mud wall provides necessary balance between the exterior and interior temperature. (Ahmed,1994). Moreover the exploitation of the raw materials used for the production of clay roof tiles often requires very little energy as most of the processes are manual.

The use and choice of these materials largely influenced by the suitability and local availability of resources and may show regional variations due to climatic and geological conditions. For instance, most of the north western part of the country (Bogra, Rajshahi, Rangpur , Dinajpur) and the area at north of Dhaka (Mymensingh, Tangail, Modhupur, Gazipur) are located at a higher elevation and greater distance from the coastal area which is comparatively less flood prone, therefore dry and suitable for mud construction. So, the mud structures are prevalent in these regions. Again not all types of soil can be used successfully for mud construction. The best natural soil for mud construction is a mixture of Argillaceous and Silicious. The pure Argillaceous clay causes shrinking and cracking of the earth walls when dry. Mud walls constructed by pure Silicious clay might not be held up even during construction. Therefore the mixture of Argillaceous and sandy clay is suitable for making mud structures. (Wolfskill, 1963) Similarly clay tiles are used as roofing materials in the areas of dry climate (Part of Khulna- Shatkhira, Jessore, Pabna, Pirojpur, Borisal, Faridpur, Bagerhat) where soil with lateritic[ii] quality is available.

Mud house and clay roof tiles have some causes of failure in their continuous use. Use of natural building material is essentially context specific which largely depends on the suitability and availability of resources and limited to only low rise construction due to its low tensile property. There is no doubt that they are not as permanent as houses made of concrete or brick. Application of mud and clay based materials is also limited to address the growing demand of housing in urban areas. So in terms of land economy, use of these materials may not be feasible. Moreover in disaster prone region (against flood, cyclone, and earthquake) these materials are subject to rapid climatic decline. Criticism against its durability, frequency of maintenance can easily be overcome with innovation and intervention of these materials. In this connection Bangladesh House Building Research Institute (HBRI) and Bangladesh University of Engineering and Technology (BUET) have conducted useful research works for the improvement of these materials. Another reason of failure in the continuous use of mud is, unlike CI sheet, mud houses do not have resale value although clay roof tiles have trade benefits.

Although mud houses and clay roof tiles have some limitations, still reappraisal of these building materials is needed to maximize the social and environmental benefits, minimize the reliance of non renewable natural resources, safeguard the most valued natural and cultural assets and contribute positively to local economic development. Mud and clay based products are still one of the most viable building materials predominantly for the poor who remain on the side lines of money-economy. Moreover the most popular materials such as brick, CI sheet with high embodied energy have severe consequences on the global warming. Again the cost of building materials is increasing day by day. In order to get a sustainable rural development a reappraisal of the traditional building material i.e. mud wall and clay roof tiles is needed on various levels.

3.0 Use of mud wall and clay roofing tiles in vernacular architecture

Mud wall and clay roofing tiles are important building materials in vernacular architecture. They are readily available and low cost, and with these there are well developed vernacular building forms existing in rural Bangladesh. Mud houses have some specific characteristics in vernacular architecture. They are briefly described below. (Fig.3)

Plinth / Base : Raised plinth is a characteristic feature of the mud houses. It is used to get protection against flood and to prevent the insect, animal population and it can take better advantages of wind flow as well. Generally the plinth varies from a height of 15 cm in higher areas to 120 cm in low-lying areas (Banglapedia, 2003).

Wall: Walls of the mud houses are usually made of mud blocks or combination of thatch and mud. One of the advantages of mud walls is that it keeps the interior space warm in winter and cool in summer (Koenigsberger, 1975). Openings of the mud houses are usually kept minimal and small to reduce glare as well as to prevent rainwater from entering the room (Banglapedia, 2003).

Roof: Broad overhang is used in order to provide shade to the verandah and give protection against rains. In vernacular architecture mainly straw, thatch, C.I. sheet etc are used as the roofing material. Besides clay roof tiles are also used as one of the chief roofing material because of its permanent nature compared to other traditional roofing materials.

Three case studies from different areas of Gazipur, Dinazpur and Shatkhira districts (see locations in Fig.1) are presented here to discuss the type and construction technique of mud houses and clay roof tiles. Present condition of the local industry and current uses were studied by field survey. Positive and negative sides of the material were investigated by interviewing the users and experts.

3.1 Mud-walled houses in Dinajpur and Gazipur

Like major part of the country the economy of this region is also agro-based and large part of its dwelling unit is still dependent on natural and organic material like mud, jute stick, and bamboo for wall construction. Majority of the mud houses are located in these regions. There are also some examples of multistoried mud houses. Even it has been observed that the more affluent section of local population is still using and up-grading mud structures.

In Dinajpur, mud walls are constructed by both layering and earth block technique but in Gazipur earth block technique is more popular. The soil required for the construction is usually collected by digging a pond or irrigation canal.

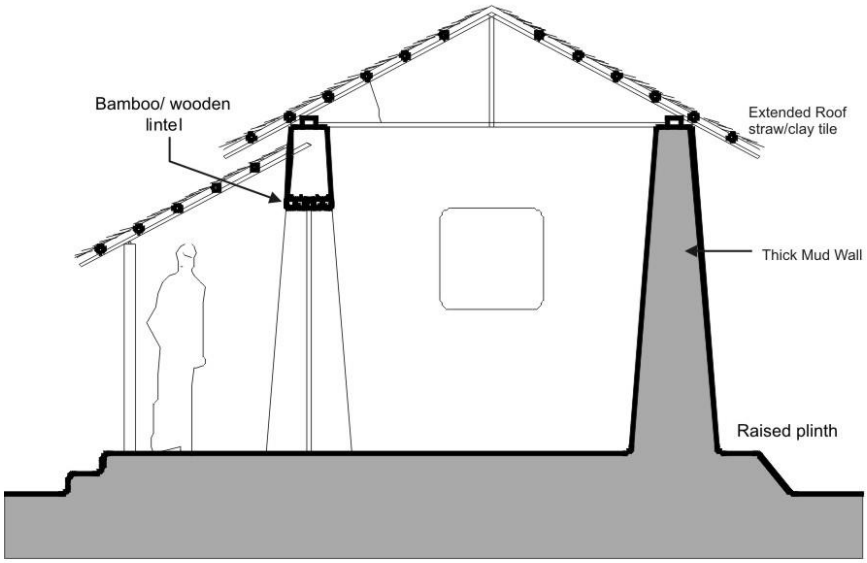

Figure 03: Section of a traditional mud house showing its different parts

Construction in layering technique

In layering technique, a raised compacted earth plinth is prepared at first, and then mud walls built on plinth in strata of 40-50 cm. Mud walls are usually reinforced with straw or rice husk. The wet mud is mixed with straw with the help of cows and buffalo. After drying of each stratum next layer is added. At the time the earth walls are erected in layers, openings for doors and windows are retained. Traditionally wooden lintels are used in the openings but these days pre-cast concrete lintels are replacing them. Roof and verandah structures are added at the last phase. A layer of mud slurry with cow dung is then applied as a finish to fill the gaps in the mud wall. Usually it takes 50-60 days to complete

a single room dwelling unit under favorable site conditions and weather. Generally the major construction works in layering technique are carried out during dry seasons of a year.

Construction with earth blocks

Large earth blocks are made and lifted into the places; and are laid in successive layers. Block in successive layers are placed after sufficient drying of the previous layers. Vertically a gap is kept between two blocks. This gap prevents shrinkage and cracks. It also admits the wind to pass through its depth which results in fast and uniform drying of earth blocks. As the earth dries and shrinks, the gaps become larger which is finally filled with mud mortar for achieving a smooth and finished surface.


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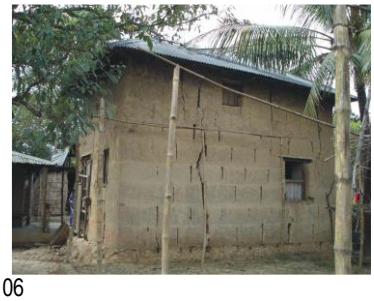
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Figure 04: Mud house in Rudrapur, Dinajpur constructed with layering technique
Figure 05: Mud wall construction in block technique.
Figure06: Mud house in Dokkhin Salna, Gazipur constructed with earth block technique.

3.2 Clay roofing tiles of Shatkhira

After the partition of India much of the art of clay tiles production have disappeared from major parts of Bangladesh. (Ahmed, 1994) Some examples of vernacular clay roofing tiles are still prevalent in the south and south western part of Bangladesh like Shatkhira, Jessore, Pabna, Pirojpur, Barisal, Faridpur etc. The information that is collected from Shatkhira on the types, construction process and installation of clay roofing tiles are presented here.


Figure 07: Flat tile


Figure 08: Ridge tile


Figure 09: Barrel tiles

Roofing tiles produced in local industry of Shatkhira can be differentiated by its shape, use and chemical composition. These include flat tiles, barrel tiles, ridge tiles etc. The flat tile is the simplest type, which is laid in regular overlapping rows. The avalilable sizes are 10”x16”, 8”x11”, 11”x17”. Each tile has a profile to allow interlocking and to protect sliding and a built-in channel to drain the water. Mission or barrel tile is a semi-cylindrical tile made by forming clay around a log and laid in alternating columns of convex and concave tiles. There are also roof tiles for special positions, particularly where the planes of the several pitches meet. They include ridge, hip and valley tiles .

In construction process at first manufacturers collect soil from nearby agricultural land. The soil is kept open to sky. Average sized industries employ one or two people to prepare the soil. A whole day is needed to compact the amount of soil to make 3000-4000 tiles. Water is mixed with the soil and compacted with ‘leg-pressing’. Compacted soil is used to make slices of soil with the help of wooden frame. The slices are then laid in forma/dice and led into the pressing machine. It’s a hand-operated machine that uses the mechanical advantages of a large threaded shaft which is rotated by a lever and creates a downward uniform pressure on the dice. Finally tile of desired shape comes out of the dice. It is then dried in the sun for a day or two. Before burning in ‘skove kiln’ a single coat of color (mixture of pitch khoir and powder of red soil) is applied. Inside the kiln, the tiles are arranged in rows and firewood is placed in between. It

ensures equal distribution of heat. Continuous burning at approximately average 900°C (initial temperature-800°C, maximum temperature-1300°C) temperature is necessary for two to three days for desired result. (Singh, 2004).


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Figure 10: Wooden tray used to dry the soft tiles in sun before burning in kiln.
Figure 11: Pressing machine to produce tiles from forma.
Figure 12: Stacked tiles are ready to sale.

In the installation process roof tiles are arranged on the framework one by one, starting from the bottom end of sloped roof. Each upper row overlaps the immediate lower one. Every row is shifted horizontally 'half-tile' distance from adjacent rows. In most cases tiles are laid freely on the framework. In few areas holes are made in the tiles and tiles are attached to frame with nails. Sometimes little mortar is applied at overlapping portion and into the holes also. Generally an angle of 30° is maintained with the horizontal line. In Bangladesh, small-scale tile industries have limited production capability. The production is not possible all the year round due to un-favorable weather conditions during the rainy season (June to September). In rainy season they face problems to keep firewood dry and burning in the kiln.

4.0 Traditional and technical approach to solve the limitations

Several limitations of mud walled houses and clay roofing tiles are found from the above case studies which are discussed below:

- Dampness is one of the major problems for mud structure. The mud floor admits moisture rising from the ground making it wet and thus makes the mud plinth extremely vulnerable. Again compact monolithic mud plinth is sometimes not enough to withstand the intensity of flood. Addressing this issue an attempt was taken to stabilize the typical mud plinth by mixing of cement and using fired brick in foundation. This might improve the result but complete stabilized mud plinth is more expensive and harder to construct compared to the typical mud plinth.


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Figure 13: The moisture rising from the ground make the earthen wall wet.
Figure 14: Traditional mud houses erode as natural forces strike.
Figure 15: Cracks develop as clay shrinks during its drying period.

- The intense, heavy rains are likely to erode the bases and surfaces of mud walls. In the regions with heavy rainfall and flood, the rural people build their mud houses with bamboo or wooden framework inside the earthen wall. So, even if the earth cover is washed away, the building remains stable and can be repaired. Some traditional solutions against the rain are construction of large overhanging roofs and use of verandahs around the house. Moreover, application of a coat of bitumen on the mud surface is also observed. Besides, a mixture of equal amount of kerosene and asphalt at a rate of 740 grams per sq.m onto the mud surface provides optimal stabilization. Again regular re-application of coats of mud slurry mixed with cow dung, painting with lime can protect surfaces and enable mud structures to last.


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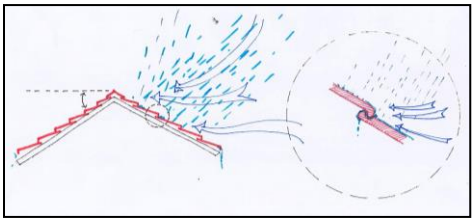
Figure 16: Large overhang is used to protect the mud wall.
Figure 17: Verandah around the house is provided to protect the wall from rain.
Figure 18: Bitumen coat over mud surface.

- Cracks develop as clayey soil shrinks during its drying period. Fewer cracks may develop by using less amount of water in the preparation of mud and by adding rice husk or chopped straw – the fiber willreduce the cracks and strengthen the mud. (Siraj and Ahmed, 2004).

- Another problem in mud houses is lack of ventilation. Traditional mud houses usually have small sized and less number of openings which result poor lighting condition and ventilation inside the dwelling, The superstitious belief of the rural people to keep small openings is more responsible rather than structural limitation of mud wall. This situation can easily be solved by cutting out an opening in the rear wall which will ensure the cross-ventilation. (Siraj and Hodhson, 2004). Ventilation is much better for houses which are constructed partly with mud and partly with bamboo screen. In this type of house the plinth and lower part of the wall up to the door level are constructed with mud while the upper part is left to cover with bamboo mat. The porous screen of the bamboo mat allows adequate cross-ventilation for the interior of building in hot humid climate.

Compared to other traditional roofing materials in Bangladesh, clay roofing tile has a great potential with simple innovation and modification. Among all its advantages, it also has some limitations which are described bellow:

- The clay roofing tile is considered as heavy material compared to other roofing materials such as thatch, straw etc ., therefore, a strong and uniform roofing frame is needed.
- Wind driven rain enters inside the house if the gaps between the clay tiles are not properly sealed. (Fig-19). Water penetration due to wind driven rain can be stopped by (a) controlling slope (Fig-20), (b) perfect arrangement of tiles on frame and (c) applying little mortar at the joining/overlapping point of the tiles (Fig-20)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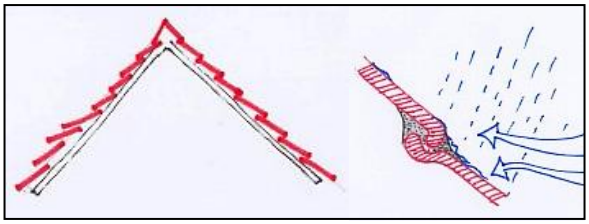
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Figure 19: Wind driven rain enters inside
Figure 20: Shows the technical means to overcome the limitations of the house if the gaps between clay roof tiles. Clay tiles are not properly sealed.

- In rainy season, in case of continuous raining for 4 or 5 days, water drops underside the roof due to condensation. This problem can be lessened by changing (a) chemical properties of soil (using soil containing more iron) and (b) controlling porosity (with optimum pressure while producing in dice) of the material and (c) lessening the permeability (with salt/lead glazing at upper surface or mix lead with varnish) of the varnish.
- In case of heavy storms, the tiles may be thrown away by gusty wind .To stop flying away during storms; tiles should be attached/tied to frames with the help of built-in earthen hook.

Thus it has been identified that the mud wall and clay roofing tile has a strong power in terms of ingredients, shape, color, texture, using technique, functionality, durability and most importantly for cultural values of contextual architecture.

5.0 METI school at Dinajpur: an inspiration towards sustainable development

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Figure 21: METI School: A modern approach but indigenous in spirit.
Figure 22: Two storied METI School showing a innovative technique of mud and bamboo construction.

The METI (Modern Education and Training Institute) is an unique educational institute which was initiated by a local NGO, Dipshikha, in 1999 in Rudrapur, Dinajpur district in Bangladesh. The two storied school building constructed with mud and bamboo is a distinguished architectural example that encourages social development, restoration and environmental responsibility. German architect Anna Heringer and Eike Roswag used local knowledge, innovative methods of construction being inspired from local techniques, locally available renewable and cost effective materials with a hope "*to set a trend in a fresh and regional architectural style that motivates people to bring their traditional construction methods- without the touch of being rustic - into a contemporary modern architecture*." (Heringer, cited in web page: www.metischool.com, 2008). The project maintains a traditional identity while embracing modernity in both its form and purpose.

The school has a brick foundation with damp proof course and mud walls constructed in layering technique. The technique of reinforcement is completely traditional where the mixer of mud and straw are used in the wall to achieve long lasting results. The ground floor of the school is constructed with mud which acts as a base for the whole structure whereas the structure of the first floor is completely made of bamboo. It overcomes the limitations of mud structures of having small openings. Number of openings with variation in shape and size, rendered the interior of the school with ample light and ventilation. It has achieved the traditional look in architectural form.

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Figure 23: The mud surface rendered with charming color and texture of mud.
Figure 24: The plastic nature of mud produced organic form of children play areas.
Figure 25: Class room in the first floor.

The school is a manually constructed structure that shows the sustainable design practice in the local context. The METI School makes substantial use of locally available materials and resources which provides flexibility to adopt the

local habits and needs; and thus gives the protection of the cultural heritage. Again the local materials offer advantages from a socio-economic point of view. The method of construction involves local skills that can be realistically developed in the community and thus contribute to the local economy. The rational use of these readily available and renewable materials has less impact on our environment through energy and resource efficiency. Thus it contributes to get ecological sustainability by saving scarcity of resouces, reducing energy consumption and imrpoving environmental quality. Again mud can be easily recycled without any environmental impact.

Towards sustainable development how successful METI school is may be a question of debate. But the designer believes that "*architecture - if we use it wisely - has the potentials to contribute in a significant scale to the development of Bangladesh's ecological balance as well as its economic independence and thus can facilitate a process of self-discovery and identification in architecture and culture." (* Heringer, cited in web page: www.metischool.com, 2008).

6.0 Observations

Followings are the observations taken from the previous examples:

- Mud wall and clay roofing tiles are reliable, much more affordable, environment friendly as compared to many other popular building materials such as C.I. sheet, brick etc. As the construction of mud house with clay roofing tiles incorporates the use of raw materials collected from locally available natural resources and the use of local means of transport, they tends to be much more economical.
- Mud as a walling material and clay tile as a roofing material are less costly in comparison to CI sheet, brick and concrete etc. While C.I. sheet roofing may be a symbol of permanence for most of the rural poor, but to a large extent, it is an inaccessible building material in terms of cost (Ahmed, 1994). That's why the use of C.I. sheet is generally limited to the construction of roof. Again the lower quality C.I sheets, which are affordable to low income groups, corrode and develop rust quite rapidly. The better sheets are more durable and also more expensive. (Ahmed, 1994).
- With proper application and installation, mud and clay based materials can be proved to be durable as there are many evidences of mud walls and clay roof tiles which are more than 50 years old.[iii]
- Under normal conditions, clay roof tiles require minimal maintenance compared to its other counterparts. For example, to prevent rust developed in C.I. sheet or to clean it off, the surface requires expensive chemicals which are not available in most rural areas. (Ahmed, 1994). On the contrary, the clay roof tiles is rust free and its' affected modular units can be easily replaced in case of any damage.
- Roof tiles are energy efficient because of its superior thermal capacity.
- Clay roof tiles can resist fire more efficiently than any other indigenous roofing material such as straw, reed etc found in rural Bangladesh.
- Clay roof tile does not decompose in wet climates and are not susceptible to destruction by pests. It can be used in any climate or region and can withstand the severest weather conditions, including rain, wind, etc.

Thus mud wall and clay roof tiles can appear as a key material in shaping the vernacular architecture because of its appearance in terms of color and texture as well as for its influence in determining the forms of architecture.

7.0 Strategies to overcome the constraints of mud and clay base building materials

The salient features of the strategies to overcome the constraints of mud structures are:

- Improvement of mud structures could be done through innovations and interventions of the construction technology to achieve the long lasting results as stated earlier.
- Greater emphasis needs to be laid to make mud and clay based products popular by solving their various limitations through traditional and technical means. Initiatives should be taken to overcome the limitations of mud structures through planning strategies i.e. constructing continuous verandah around the mud structure to protect it from the driving rain or by increasing the roof projection rather than the improvement of its chemical properties.
- Due attention should be given on construction and preservation of mud structures and clay roof tiles in order to achieve a sustainable rural development. Government should encourage for using local building materials, like mud and clay roof tiles, by giving incentive and taking initiative to build small scale public buildings with these materials with a hope to change the people's perception of the so called un-stability of mud as a building material.
- Care should be given to the preservation of cultural heritage and promotion of mud architecture in both private and public projects.

- The architects, engineers and manufacturers should be encouraged to come forward for the application and improvement of mud and clay based building materials. IAB (Institute of Architects Bangladesh) and IEB (Institute of Engineers Bangladesh) should work in coordination with House Building Research Institute (HBRI) for the development of these materials.

8.0 Conclusion

To get the sustainable solution for the development of an area, it is necessary to appreciate and use of its own potential regarding the materials and resources. In search for a context oriented sustainability, appropriate and contextual architectural expression for Bangladesh, mud wall and clay roofing tiles can play a vital role. Moreover, a cost effective solution in rural housing sector may be achieved by using mud and clay roofing tiles as a prime building material. But the major barrier for the innovation and use of these materials in architecture is attitude. From social point of view mud has always been considered as a primitive material and mud architecture is 'backward.' Because of continuous negligence of concerned authority on the use and improvement of these materials, the mud wall and clay roof tiles are still considered as temporary material which require continual repairs and maintenance and thus these are less appreciated in value.

Replacing traditional building materials with modern ones (such as brick, concrete or CI sheet) does not necessarily lead to progress. A reappraisal of the indigenous building materials is needed on various levels to contribute for local economic development. The professionals should come forward to overcome some of the existing technical shortcomings of indigenous architecture to achieve a sustainable result.

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[i] Generally clay and mud are randomly used as synonyms. Both clay and mud come from the same earthy ground. Clay can be divided into 3 types – (i) Argillaceous clay, (ii) Silicious clay and (iii) Calcarious clay. Among these, the Argillaceous clay contain Alumina (Al2O3) and Kaolinite. The Kaolinite with the addition of more water gives a clay deposit known as Kaplin Kulkarni (1968), which is popularly termed as mud.

[2].Laterite means red tropical soil-a reddish mixture of clayey iron and aluminum oxides and hydroxides formed by the weathering of basalt under humid, tropical conditions. Alumina (Al_2O_3) and silica (SiO_2) occupies major percentage of soil. Both of them along with iron control different properties of tiles like hardness, porosity, strength etc. Excess free silica reduces plasticity of soil and increases the required temperature of burning. Therefore soil, containing standard percentage of silica and alumina and more iron is suitable for tile making. Amount of pressure applied on soil determines the porosity in the tile. Extra pressure (compared to present technology in Bangladesh) would reduce porosity as well as evaporative cooling effect of the tile.

[iii] Evidence of such data has been collected from Salna, Gazipur during field survey.

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