Rajapaksha.Upendra, et al (eds), 2016, "Building the Future – resilient environments"*: Proceedings of the 9th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka, September 09-10, Colombo* pp. 250 – 261. ©

A COMPARATIVE STUDY OF THE THERMAL PERFORMANCE OF MUD AND BRICK HOUSES IN BANGLADESH

DATTA. U.S.[1], MUSTAFA. B[2]
[1,2]Bangladesh University of Engineering and Technology, Dhaka, Bangladesh
124arch0801031@gmail.com

Abstract
Different building materials respond differently to climatic conditions due to their inherent properties. The thermal properties of building components such as walls, ceiling and floors together determine the energy consumption patterns and comfort conditions in an enclosed space. The aim of this study is to compare the thermal performance of naturally ventilated mud house and brick house, typical in the villages of Bangladesh. The objective is to search for affordable and energy-efficient construction techniques suitable for rural settlements. This is pursued by analyzing mean radiant temperature, Inter-zonal heat gain and comfort level within buildings constructed from traditional and modern materials. The study focus on single storied houses with pitched roof made of CI Sheet and wall materials are traditional mud walls and brick wall with plastered surface. The thermal behavior and comfort, the patterns of energy use of mud wall and brick wall are analyzed, compared and discussed. How a building envelope reacts to outdoor conditions through graphic illustration has been demonstrated and ways in which the research can be extended by the simulations using software has been showed. This research will contribute to the promotion of passive and low energy architecture towards a sustainable future.

Keywords: *Mud house, Brick house, Thermal-performance, Simulation.*

1. Introduction

The traditional houses of Bangladesh are regarded as a good representative of warm humid tropical houses which are adaptable to local climate and well harmonized with local believe and tradition as well as local materials. As the social changes taking place, architecture will play a decisive role in the future development of Bangladesh. Although the society of Bangladesh is still strongly rooted in agriculture, people are getting more educated, privacy and individuality is gaining more importance. The village elite are building in bricks; the government or non-government organisations have buildings made out of brick or concrete; and the same applies to the temples and mosques. The hierarchy of materials is very clear. The perfect home seems to have nothing in common with the traditional house in earth, bamboo or mud.

Traditional built forms of the rural area often includes sound solution for climatic problems. The temperature difference between rural and urban areas is 4K to 5K (Mallick, 1993).According to user experience, traditional houses of Bangladesh are less hot during the daytime, but it becomes comfortable within a short time after sunset. Although these traditional building materials are highly sustainable, people are seeking for materials such as bricks, concrete, and corrugated iron sheets that are supposedly more durable. Therefore, the question arises on how the traditional house of Bangladesh can afford to control natural climate for achieving thermal comfort environment in the indoor space.

2. The context of the study

Bangladesh is located in the tropical monsoon region and its climate is characterised by high temperature, heavy rainfall, often excessive humidity, and fairly marked seasonal variations. From the climatic point of view, three distinct seasons can be recognised in Bangladesh - the cool dry season from November through February, the pre-monsoon hot season from March through May, and the rainy monsoon season which lasts from June through October. In winter there is not usually much fluctuation in temperature which ranges from minimum of 7C-13C to maximum of 24C-31C. The maximum temperature recorded in summer months is 37C although in some places this occasionally rises up to 41C or more (BBS, 2012).

3. Objective

This study compares the thermal performance of mud and brick houses in Bangladesh to show that mud houses are better suited for the naturally ventilated rural houses and provide a comfortable living condition compared to brick walled houses.

4. Methodology

Relevant published documents as well as researches previously conducted on the thermal performance of mud house structure, thermal mass of a building material, the distinct advantages of mud construction in hot- dry climate, traditional mud housing technology of Bangladesh and potential of mud construction in terms of thermal comfort have been extensively studied.

The study comprised of computer modelling, which used known thermal resistance values of the various layers of building materials, to calculate the overall thermal resistance of the system. Hourly values of incident and diffused solar radiation and outdoor temperature were used to simulate hourly temperature, mean radiant temperature and inter-zonal heat gain. The simulations were performed with recorded weather data for Dhaka, Bangladesh. For this purpose the test unit, the mud wall and brick wall buildings was first modelled in ECOTECT, and then thermal properties of the constructional elements were varied in order to measure the effect of these changes on the thermal comfort of the occupants. It should be noted here that for this simulation study, wall thickness was kept constant (50 cm) for all materials. The room was rectangular in size with a length of 27 feet and width of 18 feet, the longer side facing the south side. The roofing system considered is pitch roof of CI sheet and openings are placed on southern and northern walls. All conditions were kept constant except for the wall materials to find out the results. The comfort band is selected between18.0-26.0℃.

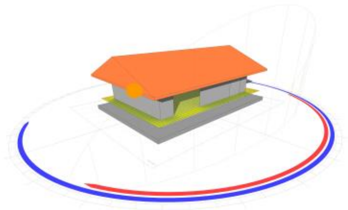

Figure 01, Study model with brick wall

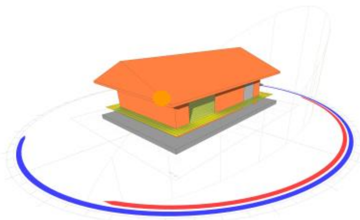

Figure 02, Study model with mud wall

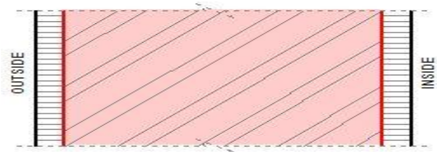

Figure 03, Considered section for brick wall

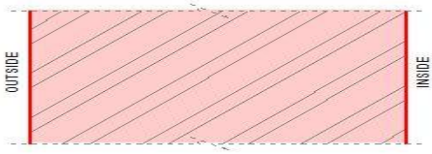

Figure 04, Considered section for mud wall

Field work is conducted with data loggers to find out the actual temperature difference in mud and brick walled house. The data was compared with the simulation results.

5. Literature review

The thermal performance of mud house structure was rarely reported and compared with another type of building (Red brick structure) in the literature. The thermal mass of a building material describes the ability of that material to absorb heat, store, and later release it either outdoor or indoor. Thermal mass can delay heat transfer through the envelope of a building, and help keep the interior cool during the day when the outside temperature is relatively higher (Amos-Abanyie, S., 2012). When thermal mass is exposed to the interior, it absorbs heat from internal sources and dampens the amplitude of the indoor temperature swing (Chenvidyakarn T, 2007).

This is particularly beneficial during warm periods, when the internal heat gains during the day is absorbed, and help to prevent an excessive temperature rise and reduction in the risk of overheating (Yam et al., 2003). A building with high thermal mass has the ability to absorb heat and provide a cooling effect which comes from the difference between the surface (radiant) temperature and that of the internal air. Szokolay (2004) accounts that absorptance/reflectance will strongly influence the solar heat input. Reardon (2010) agrees with Szokolay (2004) by asserting that porous materials with low specific heat exhibit low thermal mass effects. Additionally, good thermal conductivity and high reflectivity are also required for effective passive cooling by thermal mass.

C.V Coffman et al (1980) reported that the mud house construction have natural air conditioning effect because the rooms are cool during day time and warm during night time. The application of mud as wall material was investigated to control room air temperature for buildings by R.J Duffin et al (1981). The most common passive solar building architecture comprises of massive walls to reduce the temperature fluctuations inside a building. The popular mud-houses in Yemen city utilize this effect. The use of mud as building material is of great concerns not only for the people in hot developing countries, but also for those in cold industrialized countries in Europe and America. The engineers from developed countries have realized the special features of mud. The wider use of mud construction has a good reputation in dry and hot places because of its distinct advantages, e.g. the mud habitat suits different weather and geographical conditions as the temperature remains temperate throughout the year inside the mud building (SM. A Eben, 1990). H Algifri et al (1992) compared the thermal behaviour of adobe house with modern concrete house in Yemen and reported the potential of mud as construction material for energy saving in passive houses.

6. Mud construction in Bangladesh

Mud construction, along with other alternative materials such as rammed earth and straw bales, are often promoted as 'sustainable' building materials. One aspect that makes these materials perceived to be 'sustainable' is their embodied energy. If made locally, the embodied energy of rammed earth and mud brick is estimated to be around 0.7 MJ/kg, less than 30% of the embodied energy of clay bricks (2.5 MJ/kg) and less than 20% of the embodied energy of lightweight aerated concrete blocks (3.6 MJ/kg) (Lawson, 1996). On the other hand, the thermal performance of these materials is often overly stated in many publications. Earth walls are claimed as having "superior insulation", providing "excellent protection from extremes in climate" due to their hefty thickness, thus lowering heating and cooling needs (Austin Green Building Program, 2009).

In Bangladesh, a mud house is one of the traditional housing types that are used in rural areas as well as in the outskirts of small cities. This building type is typically one or two stories and preferably used for single-family housing. The main load bearing system consists of mud walls of 50 cm thickness (Nasir Uddin, 2007), which carry the roof load. Clay tiles, thatch or CI sheets are used as roofing materials. The application of these materials depends on their local availability and the ability of the house owners. According to the findings by Amrita Das and Mohammad Shariful Islam, the plan shape of this type of construction is generally rectangular with lengths between 20-30 ft and widths between10-15 ft (Amrita Das et al., 2007). The main structural elements are mud walls which carry the load of the roofing. The opening area is about 30 percent of the total wall area. However in present time, brick made houses with CI sheets as roofing materials have become popular mode of construction. Due to the fact that brick walls are levelled as more durable, with economic developments in rural areas more people are attracted towards brick houses. But brick walls with CI roofing can cause overheating and uncomfortable living conditions in the climatic context of Bangladesh.

Indigenous material such as mud brick has been widely used in rural areas of Bangladesh for centuries. Mud brick is environmentally friendly. It possesses high thermal capacity and acts as heat sink in extreme weather conditions. Straw which is an agricultural waste can also be used as a building material. Traditionally, it is mixed with clay or soil to produce mud brick. It also possesses good insulation properties. The energy requirement in a building can be reduced to minimum by the application of thermal mass of mud wall. Heat-gain modulation can be achieved by properly using the thermal mass of the building itself in order to absorb and store heat during the daytime hours and release it to the atmosphere after few hours.

7. Data Analysis

For the months of March, July, and December simulations are run on the mentioned model in ECOTECT. The comparative analysis of the findings is discussed below.

7.1. MEAN radiant temperature and Hourly temperature comparisons:

The Mean radiant temperature simulations show the temperature within the selected zone. By comparing with the simulated results, we can determine which material performs well to provide comfortable indoor conditions in a given time of a particular day.

There are three shaded zones and three lines on the hourly temperature graph. The blue shaded zone marks the temperature where the occupants will feel cold, the white zone marks the comfort band of temperature and red shaded zone indicate temperatures where the occupants will feel hot. The blue line represents the outdoor temperature, Brown line shows the temperature of CI roofing and Green line represents indoor temperature.

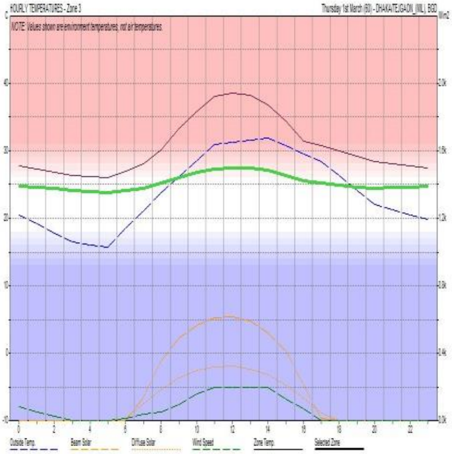

Figure 5, Hourly temperature for mud wall (1st March)

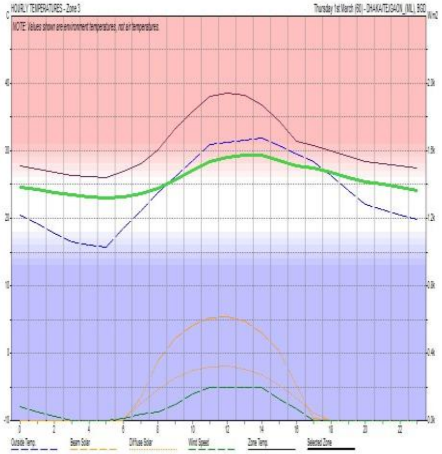

Figure 6, Hourly temperature for brick wall (1st March)

From the mean radiant temperature and hourly temperature graphs, it clearly shows that for the month of March with a mud walled house, the indoor temperature remains less than the outdoor temperature within the comfort range marked by the white shaded zone.

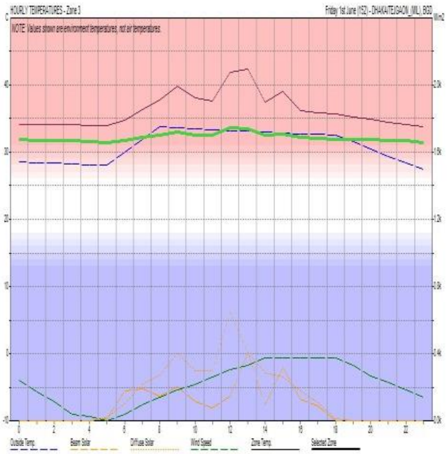

Figure 7, Hourly temperature for mud wall (1st June)

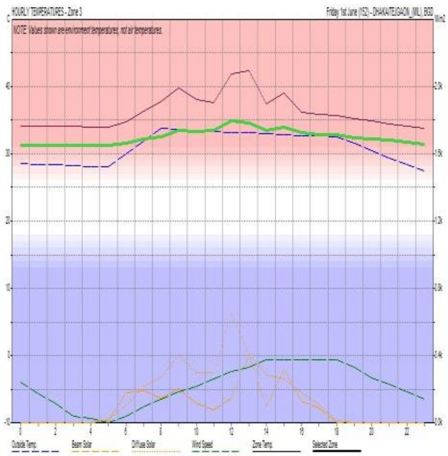

Figure 8, Hourly temperature for brick wall (1st June)

From the mean radiant temperature and hourly temperature graphs, it again shows that for the month of June with a mud walled house, the indoor temperature remains less than the outdoor temperature but for certain time of the day (from 11 am- 2 pm) the indoor temperature exceeds the comfortable range but for the brick walled house, the deviation is much higher.

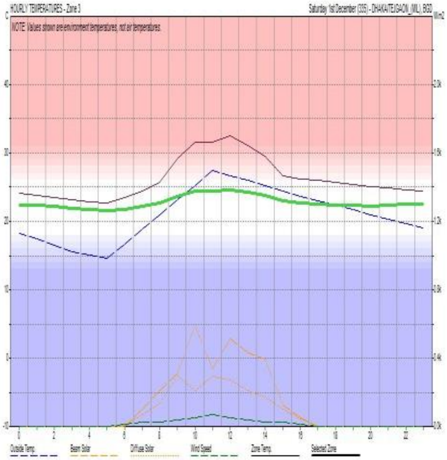

Figure 9, Hourly temperature for mud wall (1st Dec.)

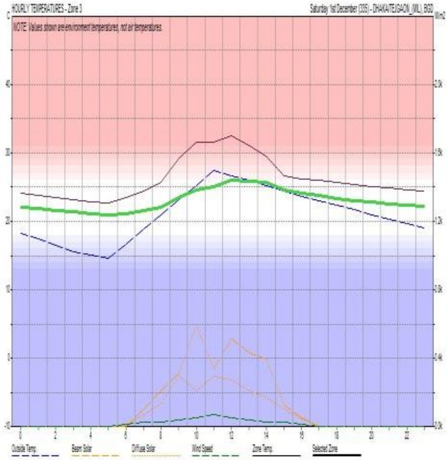

Figure 10, Hourly temperature for brick wall (1st Dec.)

From the above diagrams and graphs, it is seen that both mud walled and brick walled house keeps the indoor temperature within the comfort range. But from the hourly temperature graphs it can be seen that mud walled house shows less variation in internal temperature compared to the brick walled house.

7.2. Temperature in comfort zone:

The thermal comfort range is dependent on various factors like humidity, wind speed; solar radiation and also can vary person to person. Keeping these factors in mind, for 70% humidity and 0.5 m/s wind speed, the comfort band is selected between18.0-26.0℃ (PLEA, 2011). By running comfort simulations in ECOTECT, the following results are obtained.

Mud wall	Brick wall
Operation: Weekdays 00-24, Weekends 00-24. Comfort Band: 18.0 - 26.0℃ In Comfort: 3911 Hrs (44.6%)	Operation: Weekdays 00-24, Weekends 00-24. Comfort Band: 18.0 - 26.0℃ In Comfort: 3625 Hrs (41.4%)

So it shows that the indoor temperature in a mud walled house will remain within comfort range more than that of a brick walled house.

7.3. Passive gains or loses:

The passive heat gain or loses was analysed in ECOTECT to find out how the amount of heat is gained of lost is varied with the change of wall materials.

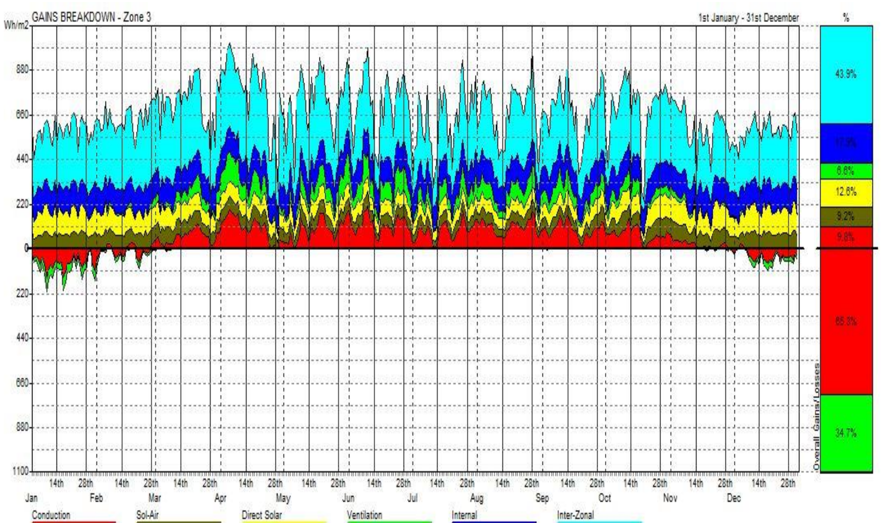

Figure 11, Passive gains or loses graph for mud walled house

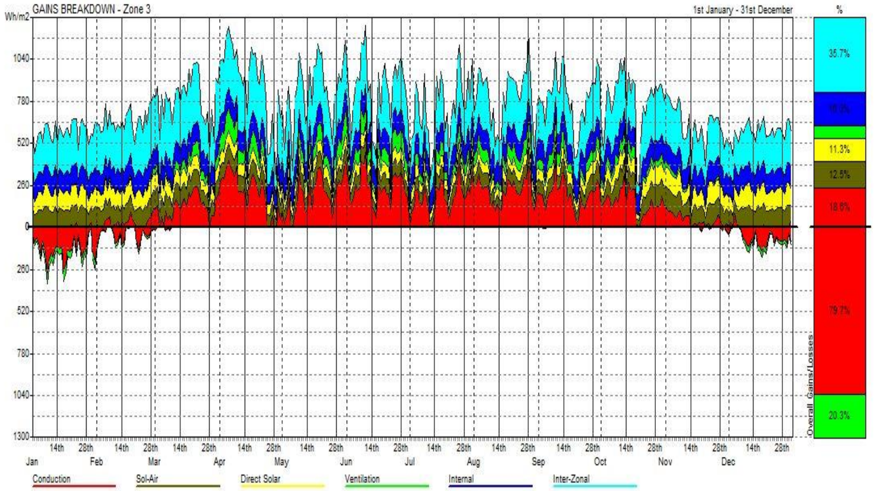

Figure 12, Passive gains or loses graph for brick walled house

From the graphs, it is clearly seen that the amount of passive heat gain is much higher in Brick walled house compared to a Mud walled house.

8. Field investigation

For field investigation, two houses were selected in the same location, adjacent to each other so that nesting conditions remain same. South east inner wall was selected for installing Data loggers in the test rooms for collection of various climatic data.

8.1. Selection of study room:

The selected rooms were similar in size and shape; both had CI roofing under which a ceiling was constructed with bamboo mat. The wall thickness varied in the mud house from 50 cm at the bottom to 20 cm at top portion. The brick wall was 15 cm in thickness. Both houses had openings on east and south walls and had partial shading from trees.

Figure 13, Selected rooms for field investigation (view from east side)

8.2. Installation of Data Loggers:

The data loggers were installed in the test room at two points at a height of 1.8 meter (close to the human height but away from children's reach) from the floor level of the test room (Fig. 14). Loggers were mounted on the wall with the help of hook and loop tape.

Figure 14, Installed Data Logger in Mud house

Figure 15, Installed Data Logger in Brick house

8.3. Field Results:

The recorded data from Data Loggers were compiled and plotted in graph. From the graph, it is seen that the maximum temperature recorded in the mud house was 31.5°C while for brick house it was 33°C.

The maximum temperature recorded in mud house was at 3:06:12 PM, while in brick house it was at 2:17:29 PM which shows a longer time lag for the Mud house. The graph also shows that in Mud house, temperature and humidity fluctuation is less than Brick wall house resulting in a more comfortable living condition.

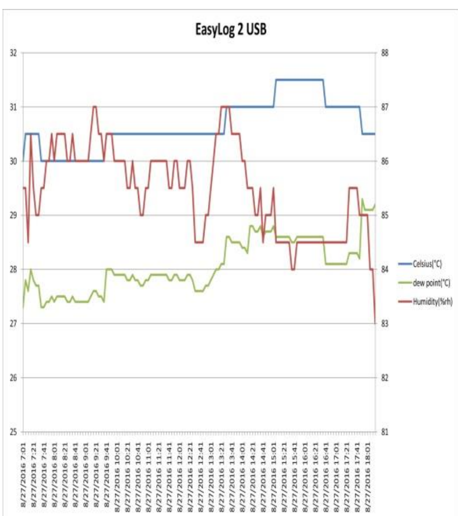

Figure 16, Temperature, RH and Due point in Mud house

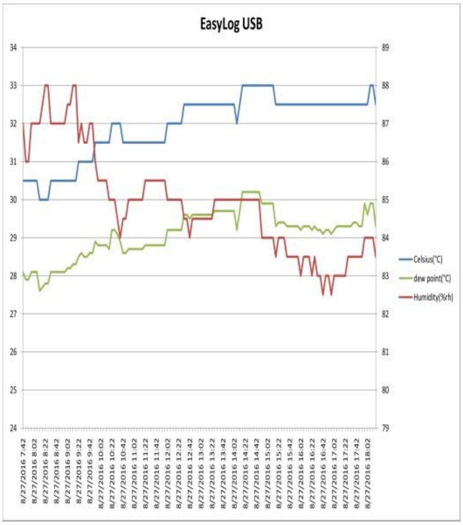

Figure 16, Temperature, RH and Due point in Brick house

9. Findings and remarks:

From simulation, it can be seen that the indoor temperature in a Mud walled house will remain within comfort range more than that of a Brick walled house. The amount of passive heat gain is much higher in Brick walled house compared to a Mud walled house.

From field data, it was observed that Mud house showed lower temperature compared to Brick house. Results show a longer time lag for the Mud house which can reduce cooling loads.

The study was conducted only for houses with CI sheet as roofing. Further studies can be conducted to show the impact of roofing material in the indoor temperature and find out whether the conditions can be further improved in the Mud house with the use of other types of roofing. Lower indoor temperature can result in less consumption of energy and reduce carbon emission. By using Mud or Earth as building material we can promote a sustainable living environment and reduce thermal stress.

10. Conclusion

The comparisons between mud walled and brick walled house reinforced the fact that mud as a building envelope keeps the inside of the hut cooler in summer than outside and warmer than outside in winter in comparison with brick wall. However the cooling effect of these traditional mud houses can be further improved and thermal comfort conditions inside the huts improved by proper design considerations.

References

Amrita Das, Mohammad Shariful Islam, Dr. Md. Jahangir Alam, Nusrat Hoque (2007), HOUSING REPORT Mud House of Bangladesh.

Amos-Abanyie, S. (2012). Effects of Thermal Mass, Window Size and Night-Time Ventilation on Peak Indoor Temperature in the Warm humid Climate of Kumasi, Ghana.

Austin Green Building Program, 2009. Sustainable Building Sourcebook. Chapter: Materials.

BBS, 2015, Statistical Yearbook of Bangladesh: 2015, 32nd edition, Bangladesh Bureau of Statistics (BBS), Government of the People's Republic of Bangladesh (GOB), Dhaka.

Chenvidyakarn T (2007). Passive Design Techniques for Thermal Comfort in Hot Humid Climate

C.V Coffman, R.J Duffin, G.P Knowles (1980), Are adobe walls optimal phase shift filters.

H Algifri, BS. M Gadhi, B. T. Nijaguna (1992), Thermal behavior of adobe and concrete houses in Yemen.

Lawson, B. 1996. Building Materials Energy and The Environment, RAIA Publisher, Canberra.

Mallick, F.H., 1993, Florence, Italy, "Alternative Roof Insulation Possibilities for Modern Urban Structures in Bangladesh". Solar Energy in Architecture and Planning, Proc, 3rd European Conference on Architecture.

Nasir Uddin (2007), A study on the traditional housing technology of Bangladesh.

PLEA 2011: Architecture & Sustainable Development : Conference.

R.J Duffin, G. Knowles (1981), Temperature control of buildings by adobe wall design.

Reardon, C. (2010). Passive design: Thermal mass. In Downton, P. (editor) Your Home Technical Manual. Australia: Australian Government – Department of Climate Change and Energy Efficiency.

SM. A Eben (1990), Adobe as a thermal regulating material, Solar Wind Technology, Vol. 7

Szokolay S (2004). Introduction to Architectural Science: The Basis of Sustainable Design.

Yam J, Li Y, Zheng Z (2003). Nonlinear Coupling between Thermal Mass and Natural Ventilation in Buildings.