INDIGENOUS RURAL HOUSING AND ITS INDOOR THERMAL PERFORMANCES BESIDE THE PADMA RIVER BANK AREAS

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ABSTRACT

A unique geographic location, coupled with climate change impacts, has made Bangladesh one of the worst victims of natural disasters. 'Living with disasters' is a cruel reality for the people of Bangladesh, and rural housing is one of the major sectors which is badly affected almost every year. This study focuses on one of the primary problems of traditional vernacular dwellings beside the Padma riverbank areas, which is the overheating of indoor spaces due to changing demand of building materials as well as harsh, barren landscapes. This empirical research was conducted by doing surveys and analyses about the available building materials, housing characteristics, homestead layouts, space-use patterns, and environmental conditions on the northern side of the Padma riverbank areas, at Munshigonj, Dhaka. Again a quantitative method of analysis was carried out for assessing indoor thermal environments of a few randomly selected houses with the help of a pocket weather meter. The surveys reveal that these houses were vulnerable to recurrent natural hazards, and their indoor environment was relatively uncomfortable. But in terms of affordability and availability, they are clearly optimum and sustainable. It may be possible to suggest ways and means of improvement of the physical environment of rural housing in such a way as to improve their indoor thermal performance and reduce vulnerabilities.

Keywords: *rural housing, vernacular dwelling, indoor environment, thermal comfort, natural hazards, riverbank areas, vulnerabilities.*

1. INTRODUCTION

Indigenous rural housing construction and its overall layout in certain localities develop according to the needs of inhabitants under a set of geographic features. Again, climatic variability, economic reasoning, and changing trends of human need have always been a foremost apprehension in any housing technology being practiced, especially among those groups of people who have been living in close association with nature for years. In order to adjust with natural calamities and environmental disasters, these people have generated a traditional paradigm of well-protected, sustainable, and ecologically-sound housing technologies which have been changing due to the presence of several factors. Demographic growth, shifts from rural to urban areas, resource depletion caused by natural as well as man-made reasons, and significant changes in expectations and life styles, all combine in their various ways to erode the viability of traditional approaches to shelter provision and the usage of building materials. However, during the past few decades, due to the advent of a cash economy (Mitchell and Bevan, 1992), industrialization, and population pressure (Alauddin et al. 1995) traditional housing is declining, or changing in form and layout. Thus, inappropriate use of materials and construction methods, fuelled by populist notions of wealth in rural housing, creates unhealthy and uncomfortable indoor environments.

Bangladesh lies in the northern hemisphere, with a composite monsoon climate having a rather long warm-humid season (Ahmed 1994). It is a generally held view that traditional houses in this region are more sympathetic to the prevailing climate, and are well collaborated with local beliefs and traditions as well as local materials, which in turn provides comfortable interiors. Again, the Ganges-Brahmaputra and Meghna river basin make this country one of the most disaster-prone regions in the world. Thus, rural life has always had a slow, steady pace here, broken only by changes of season, celebrations of their life cycle, and by natural calamities. The region already has a very critical geographical location along with poor economic conditions, and the impacts of floods, tropical cyclones, storm surges, and bank erosions are high and heavy on the housing, physical infrastructure and the life and livelihood of the people. However, the advent of frequent natural disasters and the current scarcity of natural resources have greatly affected the traditional rural housing process. Thus in rural Bangladesh, affluent households are shifting to manufactured materials like C.G.I (Corrugated Galvanized Iron) sheeting due to its widespread availability, portability and durability. As a result, the quality of housing, both within the interior and on the exterior, especially beside the riverbank areas, is declining. In addition, there is an acute shortage of land in this region due to widespread bank erosion. This leads to overcrowding and places further strain on household infrastructure, which has direct and immediately apparent negative consequences on the health and well-being of the rural people beside the Padma riverbank areas. The Padma is a major trans-boundary river in Bangladesh. It is the main distributary of the Ganges, which originates in the Himalyas.

This paper primarily traces the housing typologies and the usage of building materials beside the north bank of the Padma River, examines the indoor thermal performance of these typologies, and suggests improvements to it, especially with regard to building materials. The ultimate aim is to provide guidelines regarding a safe, sound and healthy house, which safeguards its inhabitants from the adverse effects of natural calamities.

2. RESEARCH PROBLEM

Bangladesh, with a population of roughly 150 million people (Central Intelligence Agency, 2009), is a country that is witnessing large-scale natural disasters these days. It is situated on low land, to the east of the Indian Peninsula, and it is crisscrossed by more than 230 rivers and their tributaries (Islam and Islam, S. 2005, p.589). Over the flat, deltaic country of Bangladesh, monsoon-generated flooding covers an estimated 20 per cent of the total land area, and very severe floods may cover as much as half of the country (Rogers et al. 1989, cited in Smith 2001, p.262). In fact, the rivers which cover about 3.4 million hectares of lands are also susceptible to widespread bank erosion. An ever-increasing number of people are living in remote or ecologically fragile parts of the country, such as river islands (*chars*) and cyclone prone coastal belts, which are especially vulnerable to these natural disasters. Due to the severe attack of a natural disaster, the consequent sufferings, and a lack of organized support, people on the riverbank areas have to formulate and undertake various adaptation strategies in their own fashion. It is quite a disappointing fact that the land dislocation and population displacement due to riverbank erosion and flooding attacks have received no specific attention either by social scientists or by the government in Bangladesh (Zaman and Wiest 1985; Abrar and Azad 2004; Chowdhury and Kabir 1991; Halli 1991; Rogge 1991). Traditionally, people have developed different kinds of coping strategies related to their livelihoods. Of the indigenous responses to disasters in Bangladesh, housing techniques are also adapted according to the risk posed by floods and erosion. People use building materials which are easily movable and less susceptible to the damage caused by riverbank erosion and seasonal flooding. This may lead to inappropriate choices in the physical development of homes, such as the use of corrugated iron or that of PVC and plastics showing in Fig.1. Conventional wisdom about building and construction has a tendency to be diverted to inappropriate use of materials and construction methods, fuelled sometimes by populist notions of wealth or durability. Scientific knowledge about the treatment and processing of natural materials is needed to improve permanency, as these materials require less maintenance, provide better overall thermal performance, and do not harm the existing environment (Mallick and Ali 2003; Stulz and Mukerji 1986; Seraj and Ahmed 2004; Ahmed 2005). Again, due to land crises caused by repeated bank erosions, people tend to shift to safer places, like under the shelter of some relative or neighbors'

Figure-1: Inappropriate choice of building materials like C.I sheet & PVC sheeting.

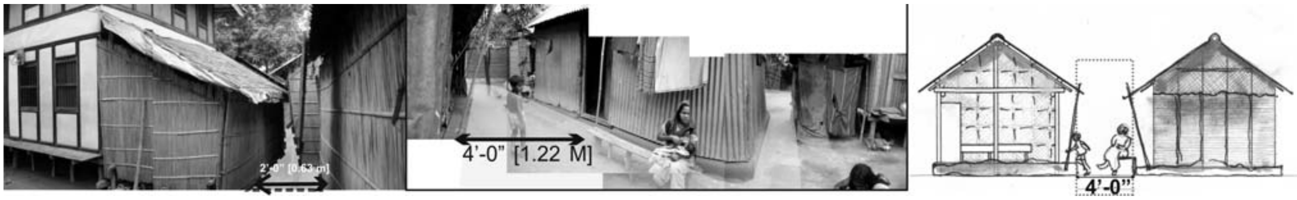


Figure-2: Congested outdoor spaces due to land shortages caused by riverbank erosion.

homesteads, beside the highways, or sometimes even to more vulnerable places like newly emerged islands (*char*) in the rivers. This in turn creates more congested microclimatic situations, shown in Fig.2, where people reuse materials for rebuilding their hut.

Each year disasters repeatedly destroy houses and reduce a family's capital, which in turn increases the family's vulnerability to future hazards. Houses are also getting more vulnerable due to repeatedly being rebuilt with the same building materials. For this reason C.G.I sheets are widely used as a roofing material for durability and to reduce maintenance costs. As a result, the indoor environment gets less appropriate day by day. The roof is the topmost element of rural houses, and is subjected to extensive solar radiation. After that, the vertical wall surfaces increase the internal air temperature. To improve the indoor thermal performance and to understand the impact of vertical walls in heat gain and indoor thermal comfort, analysis was done by elemental breakdown. To understand the impacts of microclimate, the whole study was conducted for two different microclimatic conditions beside the Padma river bank. This study is intended to investigate the effects of suitable bioclimatic design for rural housing beside the Padma riverbank areas, in order to prevent overheating conditions indoors, and to lower the maximum indoor temperatures below the ambient temperature in a tropical or monsoon climate. Finally, the aim is to provide guidelines for indoor thermal comfort for the occupants, as well as to provide high levels of self-sufficiency in energy, by using methods that the locals have created themselves.

3. RESEARCH METHODOLOGY

A survey was conducted to provide a knowledge base for the study and to gather information about related climatic issues and traditional rural housing along with indigenous building materials in the given context. This search helped in getting to know about the parameters for indoor thermal comfort and their necessity in energy efficiency as well as their relation to human wellbeing. This gave a theoretical basis for measurement and data analysis during field surveys. It has also helped in providing design guidelines for creating comfortable indoor environments in traditional rural houses around the Padma riverbank areas, Munshigonj, Dhaka. This research investigated, through an empirical survey, the rural homestead forms beside the Padma riverbank areas, indigenous housing construction technologies and building materials, and the indoor spaces of individual houses. Three homesteads were surveyed through random selection from two distinct microclimatic situations at Hasal-Banuri union in the district of Munshigonj, Dhaka. A fill-out questionnaire survey and observation surveys were the key analytical tools in this study. This analysis was also conducted in a quantitative method for indoor thermal analysis which measured both indoor and outdoor temperatures (DBT, deg Celsius) by using Kestrel 3000 Pocket Weather Meter. Data were collected on two different days of August at regular intervals of one hour, from 9.00 AM to 6.00 PM. Measurements were taken at different positions (**Fig. 19**) within the houses and also at their immediately outdoor environment. Finally, a subjective assessment of thermal comfort in these indoor environments was done based on the obtained data and statistical analysis.

4. TRADITIONAL RURAL HOUSING IN BANGLADESH

About 80% of the people in the country live in rural settlements, and 86% of the dwelling units are located in rural areas (GOB 1993). The present facilities in respect of housing and physical infrastructures are very inadequate in the rural regions of Bangladesh (GOB 1998).

4.1 Indigenous rural housing

In most of the tropics, traditional housing is rural housing, as confirmed in a study made by Koenigberger et al. (1992, p.32). Traditionally, this kind of housing is designed by the user in his spare time, and is based on low investment and the usage of local materials, combined with the assistance of relatives, friends and neighbors. Traditional houses reflect the cultural heritage and the traditional values of the people. Housingin Bangladesh has been changing its forms and building styles throughout history in response to socio-economic forces as well as the geographic location and consequently the prevalent climatic conditions. Traditional houses are influenced by locally available materials, the climate, and the economical ability of the people. The designs of traditional houses have always maintained comfortable conditions for periods longer than their counterpart contemporary houses. But vernacular building forms are undergoing rapid changes because of industrialized building materials. The use of corrugated iron sheets has become quite popular and widespread, and the production and use of traditional building materials is consequently diminishing (Islam and Islam, S. 2005, p.589).

4.2 Climatic zone and traditional house design

Bangladesh is located in the subtropical monsoon region. There are widespread differences in the intensity of the seasons at different places around the country. On the basis of overall climatic conditions, Bangladesh can be divided into the following seven distinct climatic regions shown in Fig. 03 (Rashid 2007; BBS, 2003). According to these climatic regions, a variety of traditional houses have been developed in each of the different zones.

Rural houses are extensively protected from the effects of solar radiation by trees, which produce their own microclimate. Traditional built forms of the rural area often include sound solutions for climatic problems.

4.3 Rural homesteads beside the riverbank areas

'Homesteads' traditionally refer to dwelling units with adequate open spaces that are effectively used for productive and restorative purposes, and are typically constructed by the users who live there. Rural homesteads in predominantly floodplain landscape represent similar morphological characteristics, i.e. all the household activities are arranged around an introverted central courtyard (Hassan 1885). These are vernacular by nature, i.e. people build their homesteads on comparatively higher ground or levee, as shown in Fig.04.

In terms of space use pattern, a homestead is an amalgamation of indoor and outdoor spaces as depicted in Fig. 05 (Kabir 2004). In a typical rural homestead indoor spaces and vegetation spaces are arranged around a central outdoor space, which is termed as the *uthan* i.e. courtyard. Between the detached indoor spaces, i.e. building units, relatively smaller outdoor spaces serve as secondary yards, which connect other, larger open spaces and/or vegetation spaces. Indoor (rooms, animal sheds, storage, granary, etc) and semi-outdoor spaces (verandah, sometimes kitchen, etc) are more

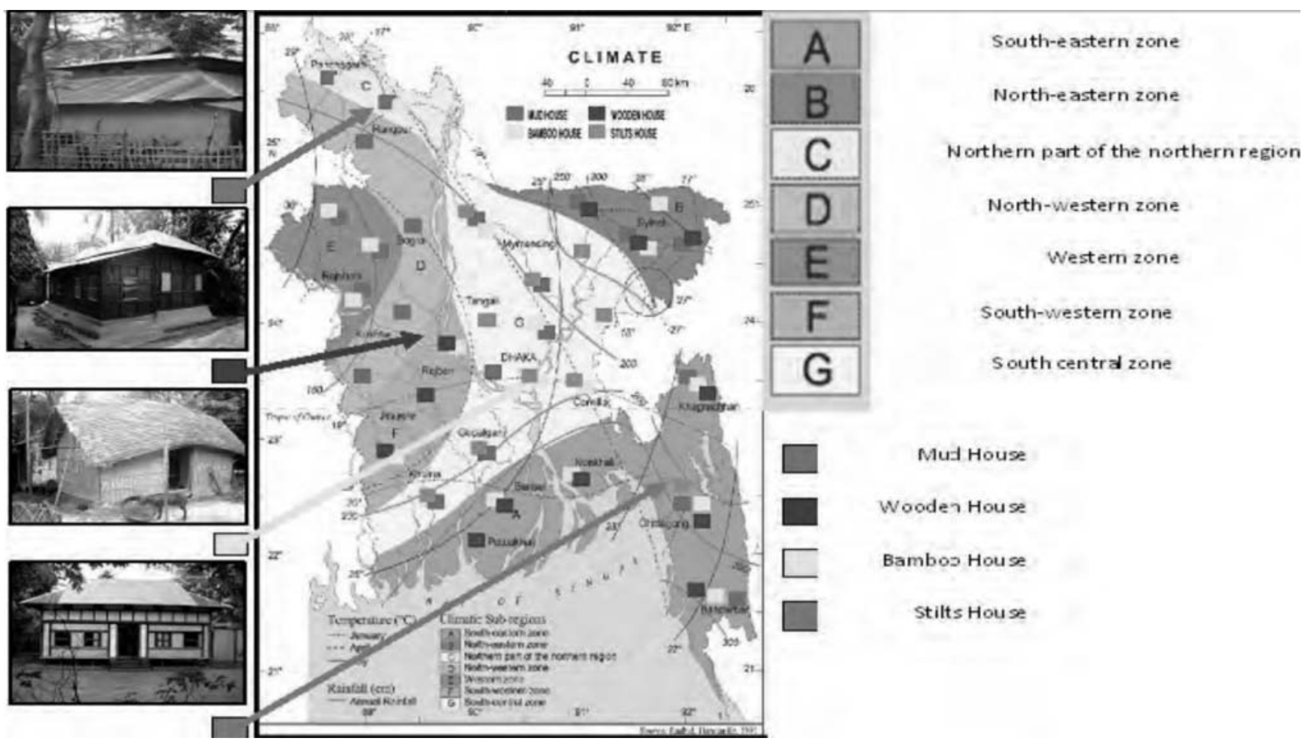


Figure-3: Different type of traditional houses in different region.

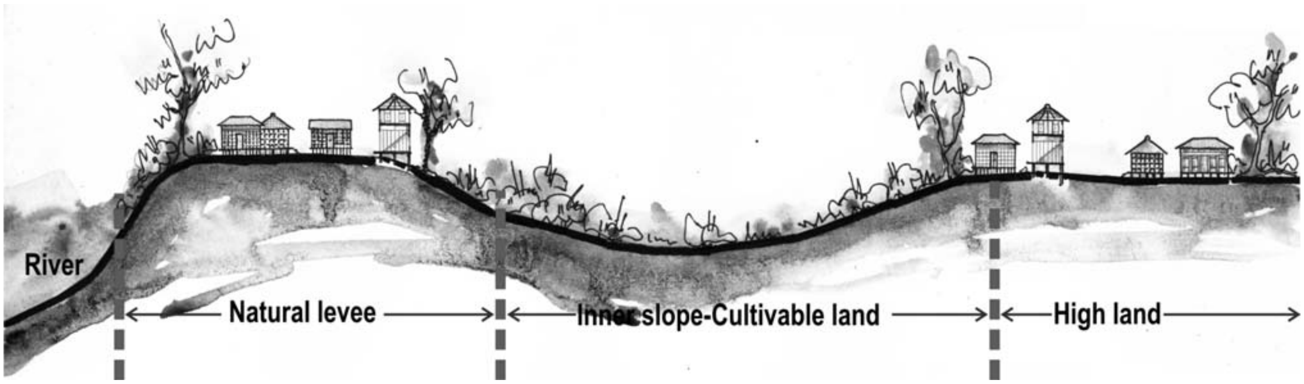


Figure-4: Section showing the settlement beside the riverbank areas.

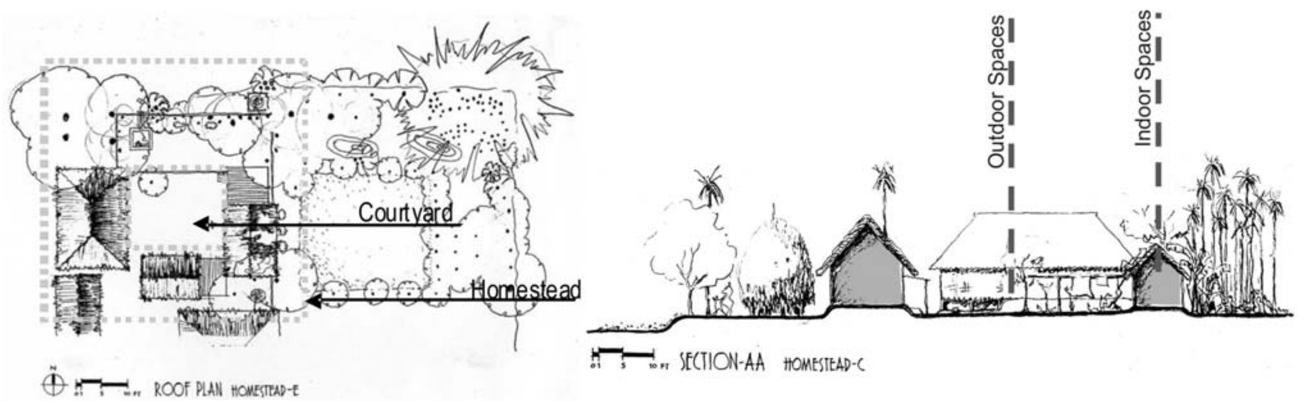


Figure-5: Plan & section of typical rural homestead.

conspicuous than outdoor spaces except the obvious one – the courtyard. Space could be defined as the three-dimensional extension of the world which is around us – the intervals, the relationships and the distances between people and people, people and things and things and things (Rapoport 1977). As a working definition for this study, space can be considered as an area of land that is enclosed, defined or adapted by people for purposes of human use (Dee 2003).

4.4 Housing form and its layout

The traditional house form of rural Bangladesh is the open courtyard type as shown in Fig. 05 (Kabir 2004) where single room units (with or without a verandah) are placed around a courtyard, with gaps between the units to allow airflow in the hot humid climate. Materials may vary depending on where the houses are situated. In the northern bank of the Padma Rivers, bamboo or dried jute stalks are using as walling material. Typically, houses in this region are raised on bamboo or timber stilts and have a floor made of split bamboo sections or timber planks. The roof is traditionally thatch but there is strong preference for corrugated iron, because of its lower maintenance and permanency in spite of high heat gain and the resultant discomfort indoors (Mallick and Ali 2003).

Houses in villages and rural settings are usually not completely built all at once, but over an appreciable period of time. Construction is phased, as rooms are built to meet the additional requirements of the growing family and as finance permits. This development process is thus an organic one: as the family grows so does the house.

The house is the symbol of the position and status of rural inhabitants. Thus the layout of housing design varies according to the socio-economic status of the household. A house in rural Bangladesh may constitute of rooms/huts around a courtyard which is the most common layout. But this courtyard gets ignored when the owners give rent to their relatives after they lost their homesteads at subsequent bank erosion allow them to build their houses on existing homesteads. The courtyard is intimately linked to the household activities; each depends on the other both in spatial terms as well as functionally. A lot of activities take place in the open in this interdependent relationship e.g. cooking, washing, drying grain, etc. Sometimes social interactions between the family members also take place here.

4.5 Housing types according to building materials

Under warm humid conditions, like those found in Bangladesh for much of the year as temperatures are not extreme, thermal mass is not sufficient enough for maintaining comfortable conditions. Thus, the walls of a building in such climates need not be thick or massive to contain the heat. Rather, they may be perforated to allow the breeze to penetrate indoors and allow convective cooling and the removal of humid indoor air. Woven bamboo walls or wooden slatted walls and perforated jali bricks are ideal for these conditions.Again, vegetation spaces in rural homesteads are host to rich biodiversity with locally native plant communities (Kabir 2004) ranging from wet to dry and sun to shade habitat conditions. According to locally available materials, the traditional houses in Bangladesh are grouped into two categories:

4.5.1 Kutcha house

A house that is made totally of organic materials such as bamboo house, mud house, jute stick and catkin grass house etc.

Walls: Organic materials like jute stick, catkin grass, straw, bamboo mats, bamboo framing. In some areas the walls are made of earth.

Foundation: Raised wooden plinth with bamboo or timber posts.

Roof: Thatch-rice or wheat or maize straw, catkin grass, with split bamboo framing.

4.5.2 Semi-Pucca House

A house that is made of traditional materials mixed with some organic and inorganic materials such as steel house, wooden house etc is referred to as semi-pucca house.

Walls: Bamboo mats, CI sheet, Timber or bamboo framing. In some areas the walls are made of earth.

Foundation: Earthen plinth; Brick perimeter wall with earth infill; Brick and concrete also used.

Roof: CI sheet with timber or bamboo framing.

4.6 Housing and seasonal disasters

One of the main characteristics of vernacular houses is that they are designed with a deep understanding and respect for nature. A comprehensive knowledge of nature's ways and the ecological balance was prevalent in traditional societies as the villagers relied heavily on nature for most of their resources. Effects of seasonal disasters on architecture are severe, especially on houses that have been built out of organic materials. Sometimes the scenario gets worse due to improper planning organizations, like in Fig. 06. The decay of organic thatch or bamboo mat used in the walls of typical kutcha houses or semi-pucca houses can accelerate during floods. The damage begins in the lower part of the walls, weakening the walls and eventually resulting in complete damage. Even C.G.I sheet get corroded when they come in contact with water, especially the lower parts of walls.

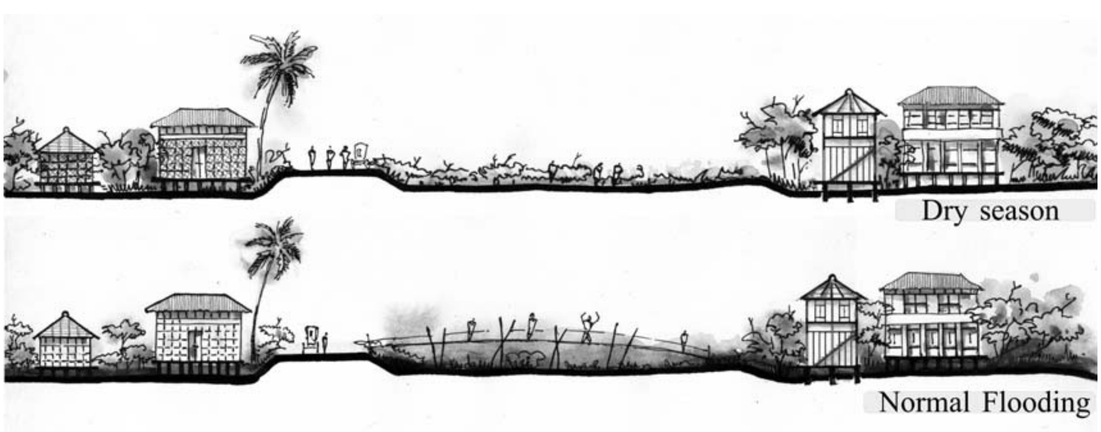


Figure-6: Detached highlands have got disconnected during seasonal flood.

5. THEORETICAL PERSPECTIVE ON RURAL HOUSING & INDOOR THERMAL COMFORT

5.1 Climate as a design generator for rural housing in bangladesh

According to the climate risk index 2009, Bangladesh tops the list as being the country most affected by climate change. Climate change affects the environment we live in, producing severe weather impacts like cyclones and floods. On a less noticeable scale, it is also gradually giving way to uncomfortable living conditions (Ahmed 2009). This again means that economically disadvantaged people in rural Bangladesh seem to survive in basic shelters and the spaces around them. In terms of space use patterns a homestead is an amalgamation of indoor and outdoor spaces. These have evolved from a deeper understanding over centuries. A closer look however reveals that these spaces do not only satisfy just their needs but can also accommodate their aspirations. But this shelter functions like a filter of the external environment. The penetration of solar radiation indoors can be favorable and healthy, or extremely unfavorable, depending on the climate, season, and building materials. Housing is a complex phenomenon, where safety and comfort are the primary requirements. A housing environment is the index of the social health and happiness, social justice, and the dignity of inhabitants (Hasan et al. 2000, p.51). Environmental factors have significantly regulated the evolving technologies of human shelter in the form of housing practice (Maguire 1996). The tropics are regarded as a region where humans evolved and comfort has often been taken for granted, but built environments are increasingly becoming issues for public concern. Comfortable outdoor spaces have a significant bearing on the perception of comfort of the indoor ambience. The demand for comfortable living conditions inside dwellings significantly increases as a result of exposure to the uncomfortable outdoors (Ahmed 2002). In the context of the Padma riverbank areas, overheated outdoor environments due to harsh barren ground have contributed to a growing preference for a lower temperature indoors. From the point of view of thermal comfort it requires reducing indoor daytime temperature below the outdoor temperature using building elements, as well as by using passive systems. Techniques for such thermal modification have been widely addressed (Givoni 1994). From a point of view of thermal comfort, climatic and physical factors other than air temperature are also important. Among various factors, the built environment acts as a mechanism of control for the climatic variables, through the building envelope (walls, floor, roof and openings) and the nearby elements (presence of masses of water, vegetation, constructions around, soil type, and others) – that is the microclimate.

The main causes of the climatic stress within rural Bangladesh are high temperatures, solar radiation, humidity and glare. To achieve climatic comfort in these riverbank areas, these factors must be controlled, besides controlling rain, floods and strong seasonal winds. Direct solar radiation is the primary source of heat gain, while the rest are secondary sources. The other major source of heat gain lies in the type of building materials used. The impact of solar radiation affects the thermal behavior of a roof more than any other part of the house, especially in tropical countries (Mallick 1993). Vertical walls are also subjected to direct solar radiation. These participate to raise the indoor air temperature above the local indoor comfort level in summer seasons. On the other hand, traditional houses of rural Bangladesh are hot during the daytime, but become comfortable within a short time after sunset due to the usage of materials with low thermal capacity.

Therefore, the question arises whether varied walling materials have any impact on the indoor temperature of traditional rural houses. For proper analysis, other identical building materials are taken for roofing, structures, etc to observe the impact of these variables on the expected findings.

The thermal performance analysis to achieve indoor comfort studied in this research involved the use of field measurement using a pocket weather meter. Data was collected from selected traditional houses in Padma riverbank areas at two different microclimatic conditions by recording the air temperature, air velocity and humidity of the indoor and outdoor spaces. According to the meteorological data of Dhaka division in 2009 (Fig. 7), data collection process was carried out in the month of August which has both a high temperature and a high relative humidity level. It is expected that the results of this project can contribute towards the accomplishment of a demonstrative example to generate a favorable effect in these areas, to improve the comfort conditions of these types of dwellings and to ultimately improve the quality of living. So the practitioners, decision-makers and researchers, through the results and experiences of this project, may have a useful source of information about the appropriate selection of walling materials from the available market sources based on their thermal performance. Significant reduction of the indoor air temperature below the outdoor level is a practical strategy in hot to warm humid summers, because of the need for daytime ventilation of the houses during the significant daily temperature range (swing). This situation suggests

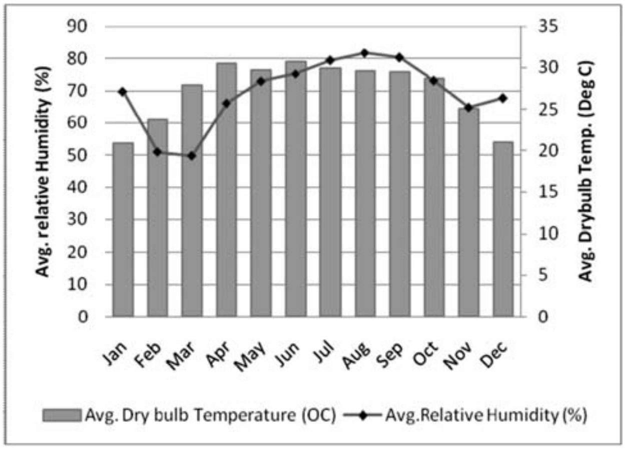
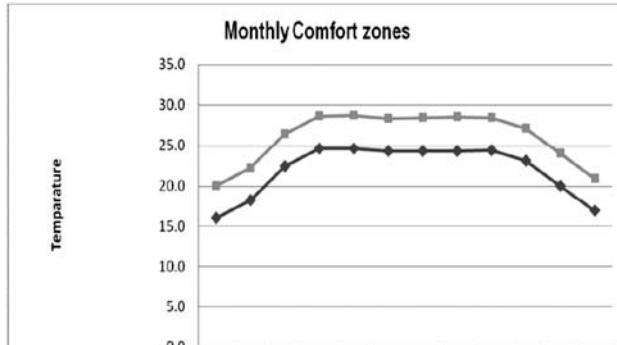


Figure-7: Mean air temperature of Dhaka division from Meteorological Data 2009.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lower Comfort Limit	16.0	18.2	22.4	24.6	24.6	24.3	24.3	24.3	24.4	23.1	20.0	16.9
Upper Comfort Limit	20.0	22.2	26.4	28.6	28.7	28.3	28.4	28.5	28.4	27.1	24.0	20.9

Figure-8: Monthly comfort zones in Dhaka, Bangladesh.

low thermal resistance of the envelope in proportion to the expected impact of solar radiation on the walls and, largely, at the roof surface (Givoni 1998).

5.2 Thermal comfort zone for Dhaka, Bangladesh

Thermal comfort has been considered by many as the major influencing factor in the indoor comfort level. The International Standards such as ASHRAE ISO 7730 Standard 55 (ISO 1984) is often used to determine the thermal comfort condition in a building by professionals. Unfortunately, current researches have obtained evidence that the standards are irrelevant in predicting the comfort level in tropical countries, especially in the countries with hot and humid climate (Ahmed et al. 1990; Mallick and Kabir 2006). Due to this discrepancy, many upcoming researches about thermal comfort in this region have been conducted aiming to establish a more relevant index or range of comfortable temperature for the tropics.

Many of the International standards produced are found to be inadequate for describing the comfort condition in the tropical climate. The majority of the field studies conducted discovered that the international set up either overestimates or underestimates the comfort condition in this climate (Nicol 2004). To predict the comfort zone in the climate of Bangladesh, Ahmed (1987, p.78) proposed Humphreys and Nicol's (1970, p.181) neutral temperature model which was found to be better fitted for our context, especially the Dhaka division (Fig. 8) (Ahmed 1987).

5.3 Housing design factors that contribute to thermal effects

The exchange of heat between the indoor and the outdoor environment is through building elements i.e. the building form. The amount of heat transmitted depends upon the characteristics of the materials forming the roof, walls and windows. Careful selection of these materials helps in creating a comfortable indoor climate. According to Gut et al. (1993, p.324) the main points to take into consideration when designing building for tropical composite climate are:

- Minimize internal heat gain during daytime and maximize heat loss at night in hot seasons,
- Select the site according to microclimatic criteria,
- Optimize the building structure and material (especially regarding thermal storage and time lag),
- Control solar radiation and regulate air circulation.
- Building orientation can affect the amount of solar energy impendent on critical surfaces of the building.

5.3.1 Building materials and thermal comfort

The effect of materials in indoor climate is its ability to transmit heat and also its thermal capacity. Light materials are desirable for hot and humid climate. Due to the problem of high temperature and humidity, cooling is important for this climate.

5.3.2 Building thermal mass

The building thermal mass is related to the exposed surface area of the material, its heat capacity and its thickness. In hot and humid climates the building should easily be able to give out the heat absorbed during the day. The use of lightweight materials during construction is therefore recommended. These materials have little residual heat when the source is removed, and hence cool down quickly.

6. STUDY AREA and ITS CONTEXT

The study area is located at Tongibari Upazila in the district of Munshigonj shown in Fig. 9 (Banglapedia, 2006) and Fig. 10. An important growth center, Hasail, is located on the left bank of the Padma River. This area is 45 km south of Dhaka district. Due to recurrent riverbank erosion, the majority of dwelling units in this region is in a very poor condition. These do not provide adequate protection from wind, rain and flood. Even the indoor living environment is seriously deteriorated and a majority of them are in unsatisfactory condition in terms of thermal comfort. The threats of riverbank erosion and recurrent flooding attacks have impelled the users to use movable housing materials. It is observed that the displacees formulated and undertook the strategy of using movable housing materials, to a large extent incidentally and to quite a considerable extent purposefully as well.

At present (August, 2010), about 68% families of this Union live beside the rural main road (government owned) and mortgaged or rented homesteads (Fig. 10). They have lost their lands either this year or the previous year due to riverbank erosion. For this reason, there is not only an increase in the shortage of housing, but the physical condition of these houses has also deteriorated seriously.

6.1 Microclimatic situations

To analyze the thermal performance of the elevated (stilt) house of the Padma River bank areas, two homesteads have been identified based on their distinct difference in land formation (fig.10 & 11). This in turn has had an impact on the surrounding microclimate. For achieving the objectives highlighted in the research as accurately as possible, the selected homesteads have similarities regarding the typology of houses, layout, orientation, and building materials (fig. 12). The orientations are same for each pair of comparable houses, and similar roofing materials are employed, and there are no ceiling or attic spaces. Microclimatic situation-01 has been selected, as the land formation of homestead-

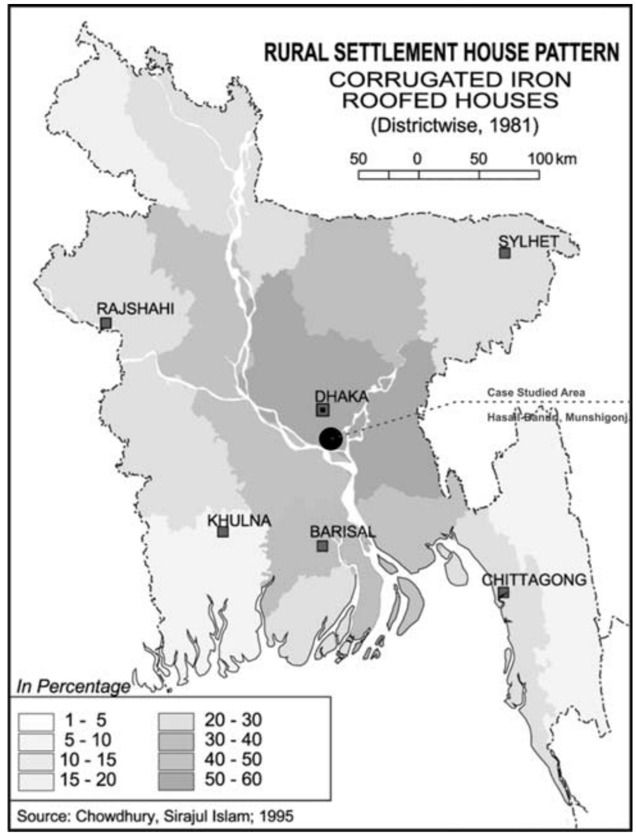


Figure-9: Study area showing in map. Hasail, munshigonj, Dhaka.Study area showing in map. Hasail, munshigonj, Dhaka.

01 is clayish soil with lots of vegetation (fig. 13). Microclimatic situation-02 has been selected due to sandy soil formation with barren landscapes of homestead-02 (fig. 14).

6.2 Housing characteristics

The houses in the northern bank of the Padma River are non-engineered or 'Kutcha' housing. There are fewer variations in the architecture and the methodologies used in this area. **Fig. 15 (**Bangladesh population census, 1997 & field survey) shows the building materials used for the walling and roofing of typical housing in this region.

In planning layout, most of the houses are single roomed and their length:breadth ratio is about 3.3:1 (Fig. 16). Multiple roomed houses are rare in this region. Sometimes addition to the older part of the house is visible, but it is usually small in percentage. Almost all houses are arranged around a courtyard, but due to land shortages, this tradition is gradually dying out.

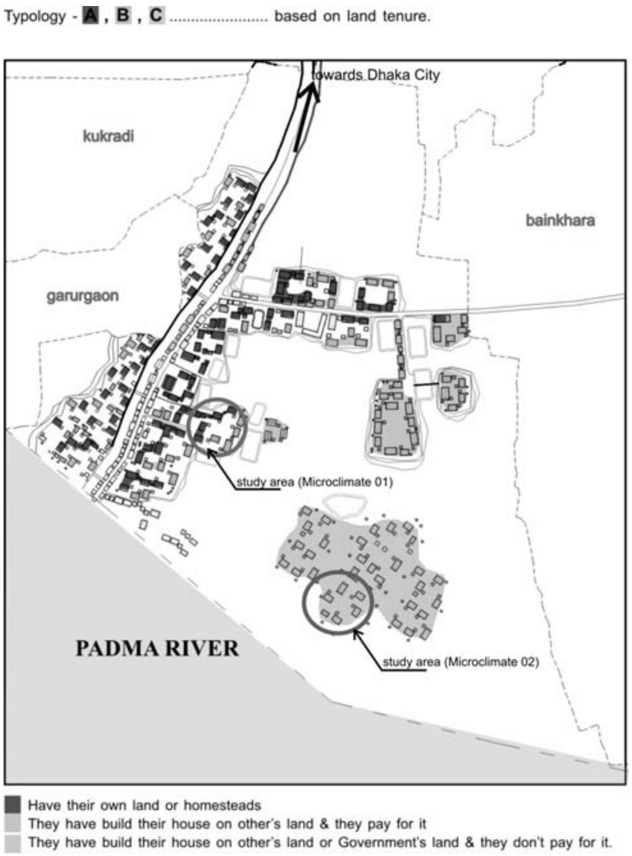


Figure-10: Housing typology based on land ownership (showing study area).

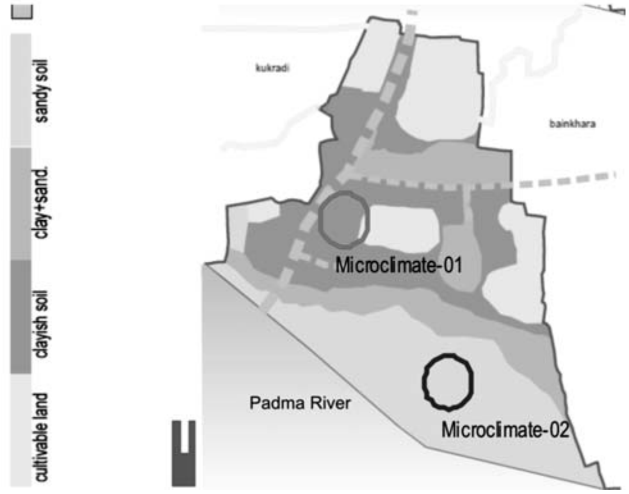


Figure-11: Showing the different type land formations.

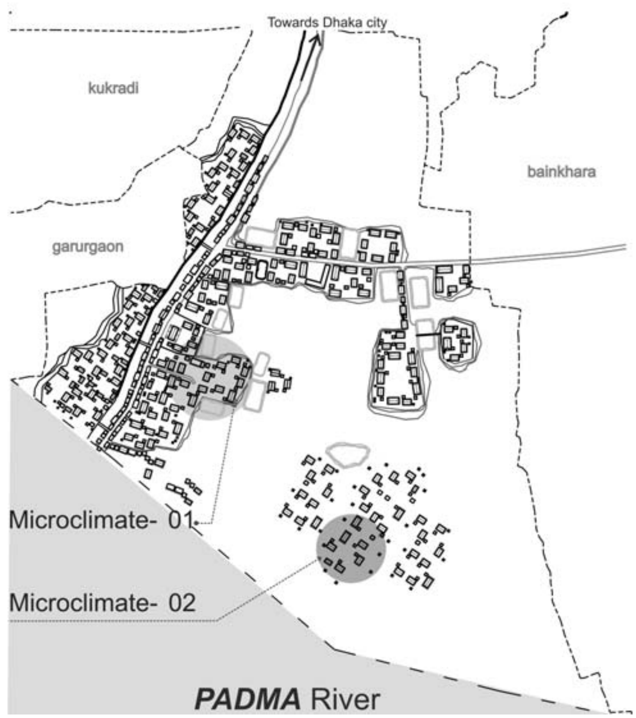


Figure-12: Showing existing built forms.

The materials used for housing in the Dhaka division indicate that the percentage of materials used for roofing are: straw/jute sticks 13%, C.I. (corrugated iron) sheet 60% and cement/flat roof 27% (Bangladesh population census, 1997). Again, the percentage of the stilt house is higher than other types of traditional houses in these areas, especially in the Padma riverbank areas. Houses in these regions are on stilts, to prevent damage from frequent seasonal flooding. As C.I sheets are the only roofing material that is used predominantly in these areas, thermal performance will be investigated based on available walling materials. It is also evident from the field survey and Fig. 15 that there are two to three types of materials that are widely used for walls in this area.

7. ANALYSIS

Fig. 17 shows a typical house of this area. Three houses were selected from homestead 01 based on similar roofing materials, and they all had a single undivided rectangular internal space with an area of approximately 360 sft (33.46 sqm). But they all had different walling materials, namely split bamboo mat, jute sticks or straw, and C.I sheet, as shown in Fig. 18. Similarly three houses were selected from homestead 02 that had the same orientation and building materials, as stated in Table 1. All house types of both microclimatic condition '01' and '02' were North and South oriented with better incidence of solar radiation. Each studied house has one window at its north side and an entrance door at the south side.

Figure-13: Outdoor spaces of Homestead-01.

Figure-14: Outdoor spaces of Homestead-02.

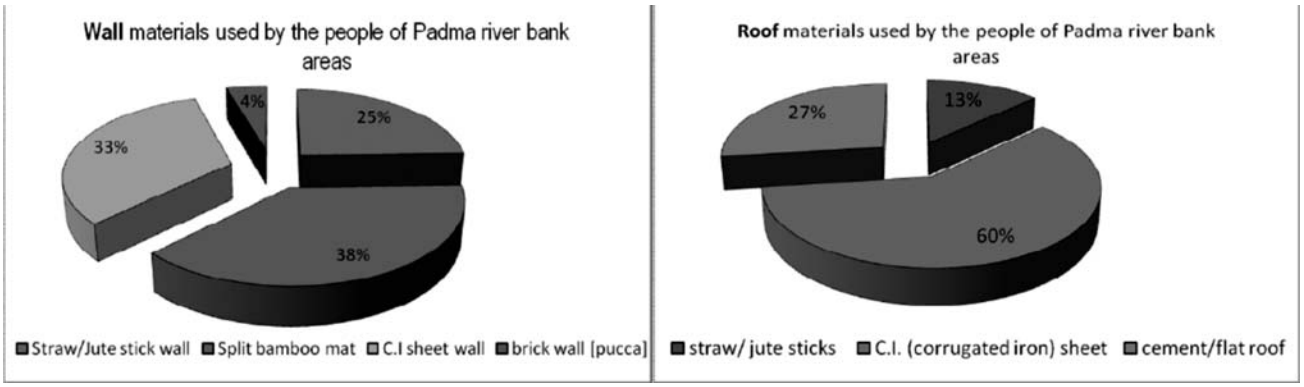
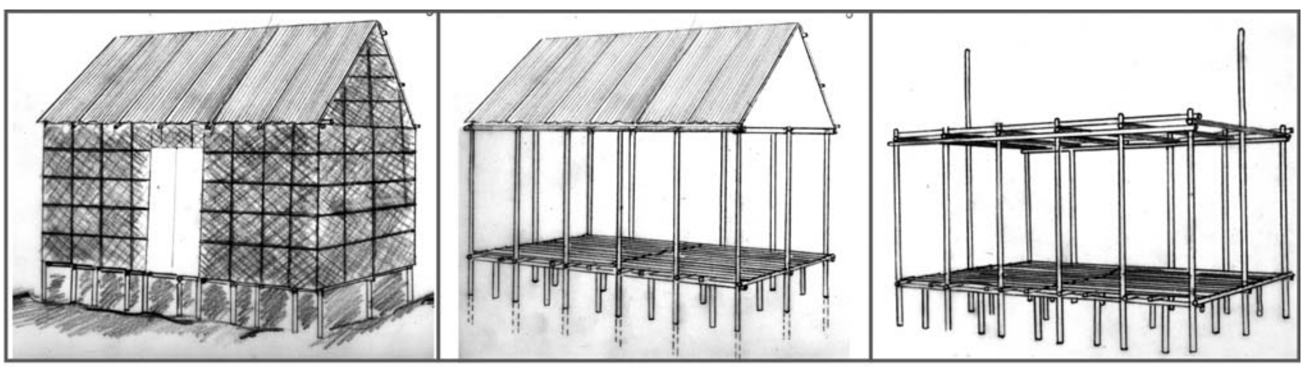


Figure-15: Percentage of building materials for roofing & walling at Padma riverbank areas, Munshigonj, Dhaka.



15'x4.5' home made of split bamboo mat

Figure-16: Typical stilt housing layout of 15'x4.5' & its internal frame.

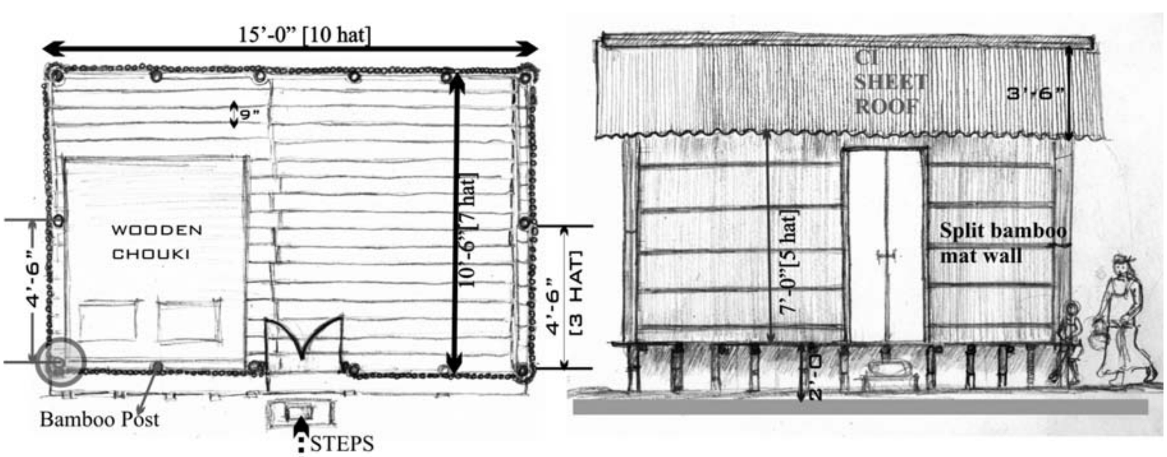


Figure-17: Plan & Section of typical house.

Figure-18: Three types of houses with their different walling material at homestead-01.

Table 01: Dwelling components and parameter settings for the case study

Item	Description					
	Homestead: **01**			Homestead: **02**		
	House Type: A	Type: B	Type: C	House Type: A’	Type: B’	Type: C’
Orientation						
Wall	Split bamboo mat	Jute stick or straw	C.I sheet	Split bamboo mat	Jute stick or straw	C.I sheet
Roof	C.I sheet	C.I sheet	C.I sheet	C.I sheet	C.I sheet	C.I sheet
Ceiling	no	no	no	no	no	no
Floor	Wood plank	Wood plank	Wood plank	Wood plank	Wood plank	Wood plank
Opening/s	1 window	1 window	1 window	1 window	1 window	1 window
Opening orientation	North	North	North	North	North	North
Entrance Door	01 at South	01 at South	01 at South	01 at South	01 at South	01 at South

7.1 Data collection processes

In order to see the thermal performance of different walling materials an investigation was carried out on six strategically selected dwelling units in two different microclimatic conditions exposed to solar radiation between the times of 09.00-18.00.

According to the objective of this research, data collection processes were conducted in one of the most overheated months of the year, August (Ahmed 1987). For data collection, two indoor points and one outdoor point were selected for each house at both microclimate 01 and 02 as shown in Fig. 19. As data was collected for only day time, the interval was one hour. According to this, 30 readings were taken in one day for each house type at each microclimate. This process was conducted on the 19th and 26th of August, 2010.

For the ease in data tabulation and analysis some annotations have been used (Table 2).

7.2 Measurements and data analysis

With the help of a pocket weather meter, temperature readings were taken at one hour intervals at previously selected data collection points (Figure: 18). The whole process was conducted for three different houses at two different microclimatic conditions (Figure: 18)

Preliminary readings from Table 03 revealed that the maximum outdoor and indoor air-temperature are recorded between 13.00 to 16.00 hrs. This temperature data also coincided with previous field surveys during the selection of two different microclimates. From the chart at Fig. 20,

Table 02: Tabular output method of Climatic data collection for three houses at two different microclimates (1 & 2)

Annotation & Description							
	Microclimate 01			Microclimate 02			Measured Variables
Outdoor Temp.	T_o (1)			T_o (2)			Temparature (^{0}C)
Indoor Temp	type- A	type- B	type- C	type- A'	type- B'	type- C'	
	Ti (1A)	Ti (1B)	Ti (1C)	Ti (2A')	Ti (2B')	Ti (2C')	
	V (1A)	V (1B)	V (1C)	V (2A')	V(2B')	V(2C')	

Table 03: Temperature readings at different locations [average data of two days at each hour has tabulated]

Time	Microclimate 01				Microclimate 02			
	To (1)	Ti (1A)	Ti (1B)	Ti (1C)	To (2)	Ti (2A’)	Ti (2B’)	Ti (2C’)
9.00	31	26	27	28.5	32	27	27	29
10.00	31	27	27.5	29	32.5	27	27	29
11.00	32	27	28	29.5	33	28	28	30
12.00	32	28	28	30	33	28	29	31.5
13.00	33	29	29.5	30	34	29	30	32
14.00	32	29	30	31	34	30	31	33
15.00	32	30	31	32	34.5	32	32	33.5
16.00	30	28.5	30	32.5	33	32.5	31	34
17.00	29	27	29.5	31	31	31	30	33
18.00	28	27	28	30	30	30	29	32

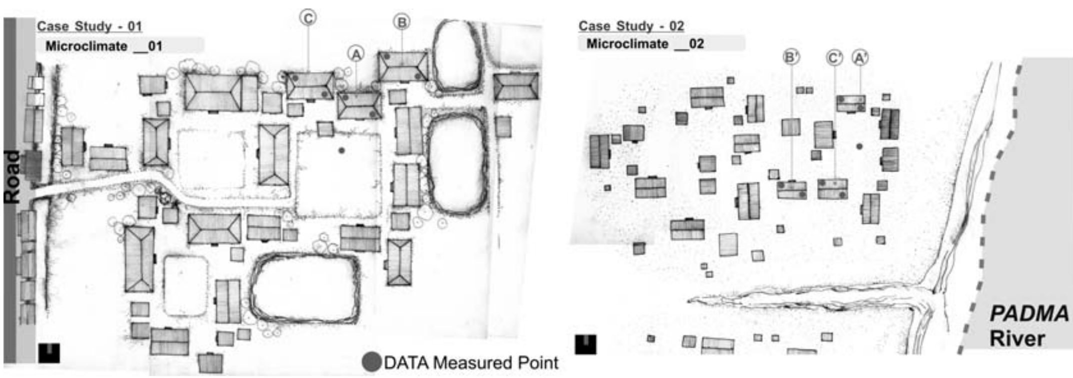


Figure-19: Data collection positions (red dots) at two different microclimates.

it is revealed that microclimatic situation 02 is hotter than microclimatic situation 01.

Surveyed data was plotted with identified comfort zone for this area as is shown in Fig. 21. For the month of August this range is 24.3-28.3 0C (Ahmed 1987).

It is evident from both charts in Fig. 21 that the indoor temperatures of house types ‘A’ and ‘B’ are comfortable only during the morning and afternoon periods. But house type ‘C’ which has both walling and roofing made of C.I sheet remains out of the comfort zone throughout the day. This statement is also made clear by the profile of indoor comfort hours (Fig. 22 & 23). From the chart shown in Fig. 23, it is visible that at both microclimates, the least hours of comfort are found in the house made of C.I sheet walls and C.I sheet roof – especially at microclimatic zone 02, which has barren sandy soil formation.

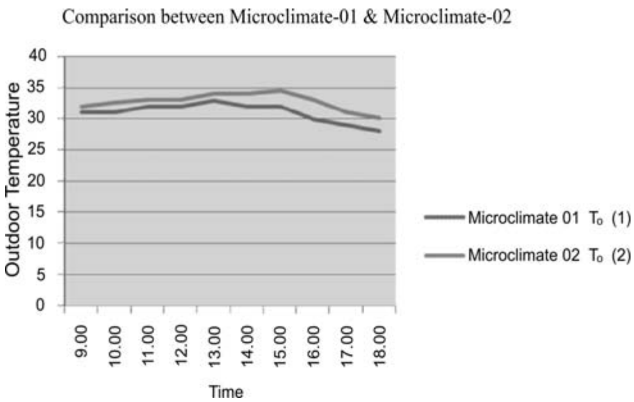


Figure-20: Comparison of outdoor air temperature between Microclimate-01 and Microclimate-02.

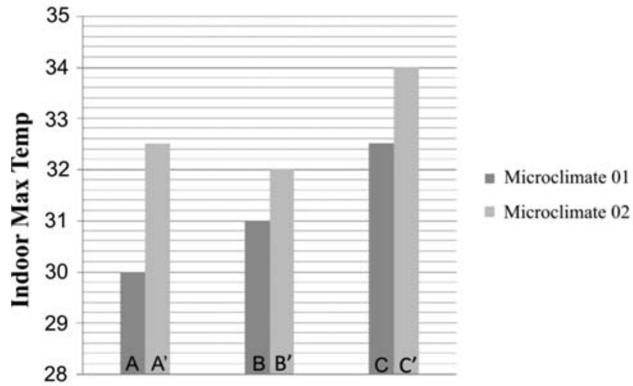


Figure-22: Comparison of indoor maximum air temperature of three types of houses at both microclimates.

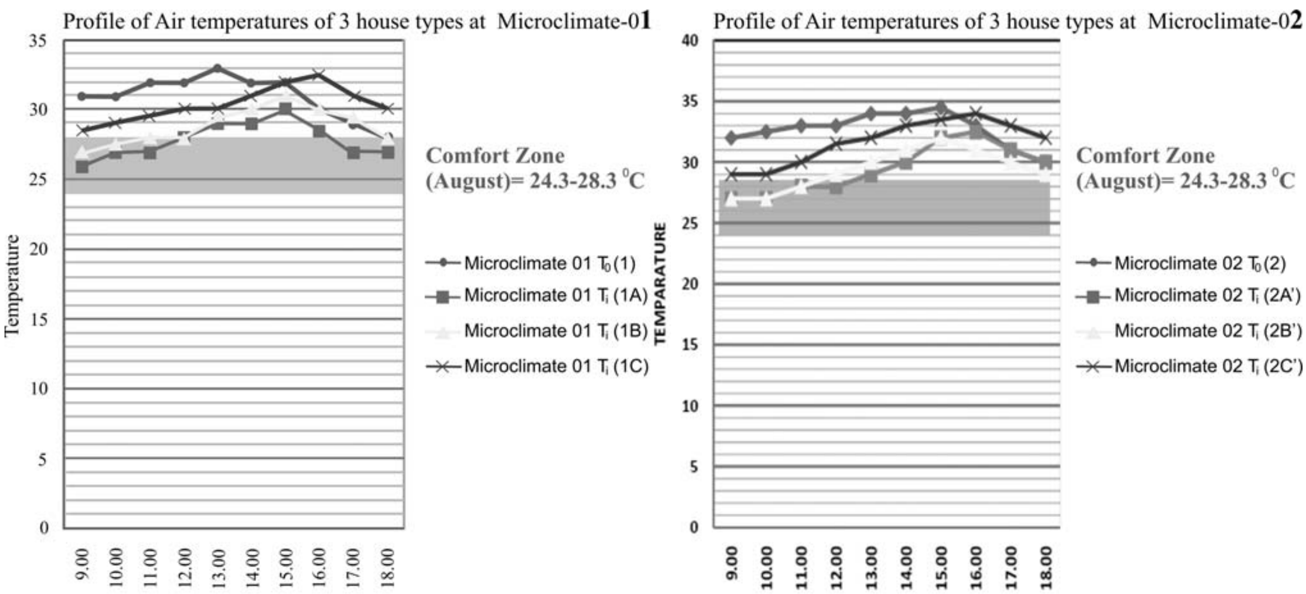


Figure-21: Comparison of outdoor air temperature and indoor air temperature with comfort zone at Microclimate-01 and Microclimate-02.

7.3 Findings

From the preceding explanation of the indoor thermal environment of three commonly built rural houses beside riverbank areas, it is obvious that these houses remain mostly out of the comfort zone, especially during summer days, due to the choice of building material, that is largely C.G.I sheeting. Situations have gone even worse due to the presence of sandy soil and the absence of adequate natural vegetation in the surroundings.

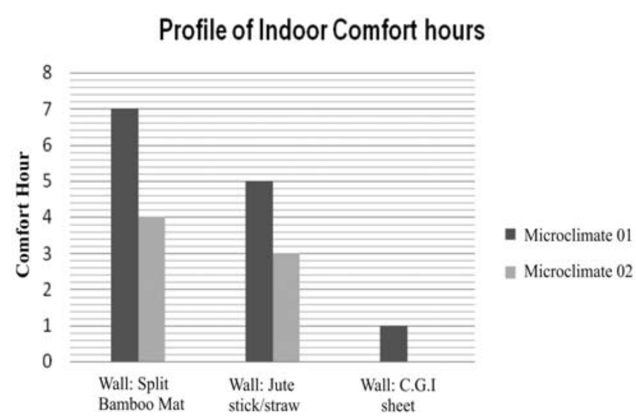


Figure-23: Profile of indoor comfort hours at day time in three house types at both microclimates.

8. CONCLUSION AND RECOMMENDATIONS

8.1 Conclusion

The envelope of the building includes walls, roof, floors and windows, among others, that is, all the building components directly in contact with the external ambient conditions. The envelope of the houses plays a very important role for achieving comfort conditions for the occupants in a dwelling. In this research, it was revealed that an envelope made of C.I sheet is not comfortable during summer days especially for those houses which are naturally ventilated. Minimizing energy use and promoting energy efficiency in hot and humid seasons requires that roof and walls are lightweight and have low emissivity of long wave radiation. Ceilings are highly desirable for protecting the interior from heat from the roof. A larger portion of walling material should be one that is locally available, and at the same time provides for a cool interior, with sufficient openings for cross ventilation. Although materials alone cannot be concluded to be the only way of attaining thermal comfort, light colored roofing materials, light colored walls and lightweight building form are primarily the potential ways of better thermal performance in indoor spaces.

8.2 Recommendations

Traditional planning and building methods were often good examples of sustainable architecture in their time, and represented good uses of local resources paired with local skills. Combined, they produced a built environment which met people's needs. But factors such as frequent natural disasters, demographic growth, abundant availability of C.I (Corrugated Iron) sheet, and significant changes in expectations, life styles, and socio-economic structures, all in combination erode the viability of traditional approaches to shelter provision. Thus these environmental problems in rural areas are not always due to a lack of resources or lack of knowledge base but for inappropriate focus on unsustainable issues (Ghosh 2003). This statement has also been proved true through this comparative analysis which provides some evidence to support the proposition that traditional building materials in house design are superior to the widespread C.I sheet. So the type A and B houses are indeed well adapted to the natural climate of region. It also provides us with a useful indicator of appropriate architectural design in response to climate. So walling with split bamboo mat and roofing with light colored reflective materials with double ceiling, supported by a wood or bamboo structure may be considered as a low to medium thermal mass. For appropriate planning solution, the central part of the courtyard should be its highest point, sloping gently (1% minimum slope) to the edges to allow drainage. Traditional building materials like wooden/bamboo structures and other walling and roofing materials should be properly treated to protect them from seasonal flooding. Finally, a house made of C.I sheet without any ceiling should be highly avoidable. From the above discussion, it is clear that to achieve thermal comfort in the composite or monsoon climate with an extensive warm humid season, solar heat gain by the building and the human body must be minimized, while heat dissipation from the body must be maximized by methods of ventilation and evaporative cooling.

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