Thermal Comfort in the Traditional Rural Bangladesh House

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ABSTRACT

Bangladesh Traditional House (BTH) is considered to be a prime example of environmental design responses to regional conditions. The house forms, building styles and materials used in construction have significant variations in different areas of Bangladesh, but one element in common is the design concept for the upper space. The upper space of BTH plays a vital role with diurnal variation of ambient environment to provide comfortable interiors. This paper analyses the above hypothesis in the traditional stilt house in the city of Dhaka. The analysis of actual performance of the traditional house may provide information on the effectiveness of applying appropriate principles of passive design for warm humid climates. Empirical studies have been performed in Dhaka city. Internal and external air temperatures and relative humidity were measured for both summer and winter seasons, for a period of six months. The data were collected in three zones: outdoors, indoor and the upper space. Results show that the BTH architectural design solution permits good passive cooling for thermal comfort during both the summer and the winter seasons even in the worst surroundings of dense Dhaka city. The upper space maintains the indoor air temperature within the comfort range for most hours of the day. The design of the upper space with operable windows has a natural cooling effect.

Keywords: *Traditional Stilts House, Upper space, Thermal Performance, Indoor environment, Thermal comfort.*

1. INTRODUCTION

Bangladesh Traditional House (BTH) represents the social heritage of Bangladesh. It encapsulates traditional form and also reflects harmony, simplicity and authenticity. Traditional housing is located abundantly in rural areas, as confirmed in a study by Koenigberger et al (1973). Traditional housing is designed by the owner and based on low investment, local materials, combined with the assistance of relations, friends and neighbors. For centuries traditional houses have been using locally available materials. Bangladesh Traditional House is considered to be a prime example of environmental design responsive to regional conditions. The house forms, building styles and materials used in construction have significant variations in different areas of Bangladesh. Perhaps the only common element is the design concept of the "upper space". Regional climate greatly affect the indoor thermal environment in BTH. In the warm humid tropical climate, buildings are overheated during the hot summer day due to solar heat gain through the building envelope and windows. From a thermal comfort point of view, it requires lowering of indoor daytime temperature below the outdoor temperature using building elements and by passive or active systems (Mridha, 2002). Techniques for such thermal modification have been widely addressed in BTH technology. Traditional house techniques confronted the environmental challenges and responded to achieve comfortable indoor environments. However, different architectural elements of BTH such as roof, wall, floor, window, need to be explored to determine their influence on the thermal performance. Thus, the design principles implemented in traditional architecture can be applied in improving contemporary architecture. Therefore, the present study is undertaken to investigate the thermal performance of a BTH design using traditional architectural principles. This paper discusses the results of a field measurement on the thermal performance of BTH carried out in the warm humid climate of Dhaka city. Evaluation of actual performance through this research can provide further improvements and direction in the advancement of knowledge and design appropriate within regions with a warm humid climate. It is the

Table 1: Seasonal and climatic variables for Dhaka, Bangladesh.

Meteorological Seasons	Gregorian Calendar Months	Ave. air Temp For 91-06 (K)	Mean RH For 91-06 (%)	Mean Rainfall For 91-06 (mm)	Mean Wind Speed & Direction For 91-06 (m/s)
Winter (cool-dry)	January	18.8	72.4	11	1.4(NW)
Winter (cool-dry)	February	21.9	67.0	27	1.9(N)
Pre-monsoon (hot-dry)	March	26.6	63.6	69	2.4 (SW)
Pre-monsoon (hot-dry)	April	28.9	70.9	120	2.9(SW)
Pre-monsoon (hot-dry)	May	29.0	78.4	342	2.4 (S)
Monsoon (hot-wet)	June	29.5	82.3	267	2.3 (SE)
Monsoon (hot-wet)	July	29.1	84.0	371	2.2(SE)
Monsoon (hot-wet)	August	29.2	83.6	335	2.2(SE)
Monsoon (hot-wet)	September	29.0	83.5	293	2.1(SE)
Post monsoon (hot-wet)	October	28.0	80.7	197	2.1(N)
Post monsoon (hot-wet)	November	24.5	75.7	26	1.3(NW)
Winter (cool-dry)	December	20.3	74.4	13	1.6(NW)

hypotheses that the performance of the upper space in the BTH plays a vital role to achieve the indoor thermal comfort environment within the context of the dense Dhaka city under such extreme climate conditions.

2A. BANGLADESH TRADITIONAL HOUSE

The traditional house in rural Bangladesh offers a fine example of regionally specific socio-cultural product (M.A.Muktadir et. al, 1985). Bangladesh is located in the subtropical monsoon region. There are widespread differences in the intensity of the seasons at different places of the country. Bangladesh can be divided into the following seven distinct climatic zones: southeastern, northeastern, northern, northwestern, western, southwestern, and south central. Different types of traditional houses were developed in different ways according to the climatic zones. In Bangladesh traditional houses are broadly divided into four types according to availability of materials and climatic disasters such as flood, drought, hailstorm, tornadoes etc.: mud houses, bamboo houses, timber houses, and stilt houses (Rumana 2007). Traditional house design also depended on climatic disasters impact the design of traditional houses. So in the hilly region mud houses and bamboo houses are found. In low land where flood occurs, elevated stilt houses are popular. Barishal, Cox's Bazar, where bamboo is less available, timber houses are built.

2B. UPPER SPACE IN BANGLADESH TRADITIONAL

The "upper space" is the most common feature of all types of traditional houses in Bangladesh, and plays a vital role in the thermal comfort of the living space. These upper spaces have a multipurpose use. The upper space is used as storage in all seasons. The upper space has a wooden plank, bamboo or corrugated iron (C.I.) sheet as the ceiling of the indoor space and another C.I. sheet with a wooden frame forms the outside roof. This accessible upper space has a secured wooden door from the main living area. The upper space is accessible by a wooden ladder. An adequate number and size of windows are built in the upper area, which are oriented along the prevailing direction of wind flow to allow cross ventilation. The upper space also protects the indoor space from direct solar radiation and heat. In flood seasons, all household things are kept in the upper space. Occasionally, during hot summer nights, people also stay in the upper spaces for comfort. The upper space wall openings are exposed to allow better airflow and ventilation. Extended roofs protect the wall openings of the upper space from sun and rain.

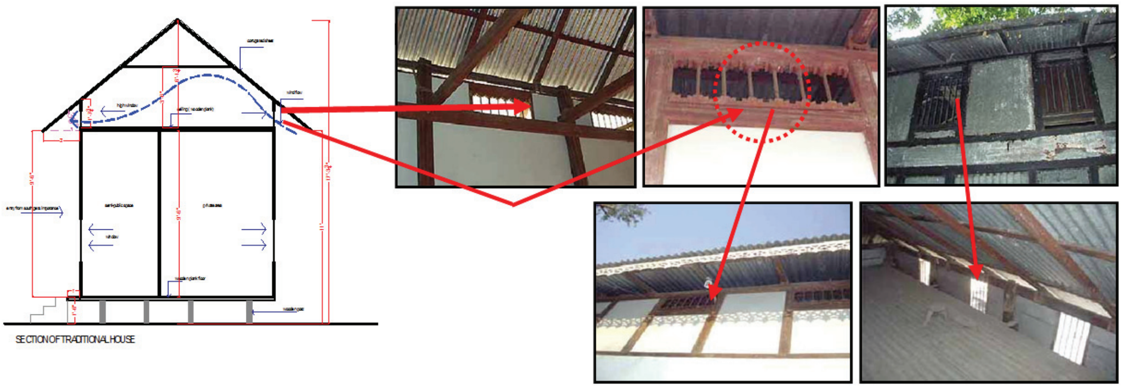

Figure 1:
Different types of wall openings in the upper space of a stilt house.

3. METHODOLOGY OF THE RESEARCH

The field study examines the thermal performance of traditional Bangladesh house with special reference to Dhaka. Extensive fieldwork was done to study the effectiveness of the traditional house upper space and its influence on the overall thermal performance of the selected traditional houses. The data of the field study was taken during the most persistent and dominant seasons: winter and summer. At the same time the most extreme climatic value were also registered during these periods.

From a previous study, it was identified that January is the coolest month and April is the hottest month for Bangladesh. The mean maximum temperature in Dhaka has its lowest value in January and progresses over the season. The temperature reaches maximum in April and decreases up to August. The mean temperature increases from January to April, then remains almost constant up to September, and decreases up to January. The mean minimum temperature is the lowest in January, increases up to June and remains fairly constant up to September and decreases after that (Karmokar et. al, 1993). Winter period in Bangladesh lasts only three months from December to February. For this reason, this field study research was carried out in the winter months of January and February. For the long summer season the selected months were March to June, because April to September remained almost constant.

Data were collected using HOBO thermal data loggers and sensors for a duration of six months (figure 3). Air temperature and relative humidity data were collected form indoor, outdoor and upper space of the selected BTH at Gulshan area in Dhaka city. To verify the air temperature of Dhaka city, data were taken per minute over five days and it was found that within eight to ten minutes, air temperature had not changed significantly. For this reason the data logger was programmed to collect data at an interval of every five minutes. With this interval, the loggers were set for seven days, and 2030 air temperature and humidity data readings were recorded on the Hobo Logger. The data was downloaded at six or seven day's intervals. Data collection started from January 10, 2007 and it was continued up to June 20, 2007.

Further, in order to analyze the thermal performance, the following methods were used for data collections as shown table 1. The percentage of opening of the upper space is different in different months (table 1). Observation on environmental factors relate directly to thermal behavior, indoor environment, air temperature and relative humidity.

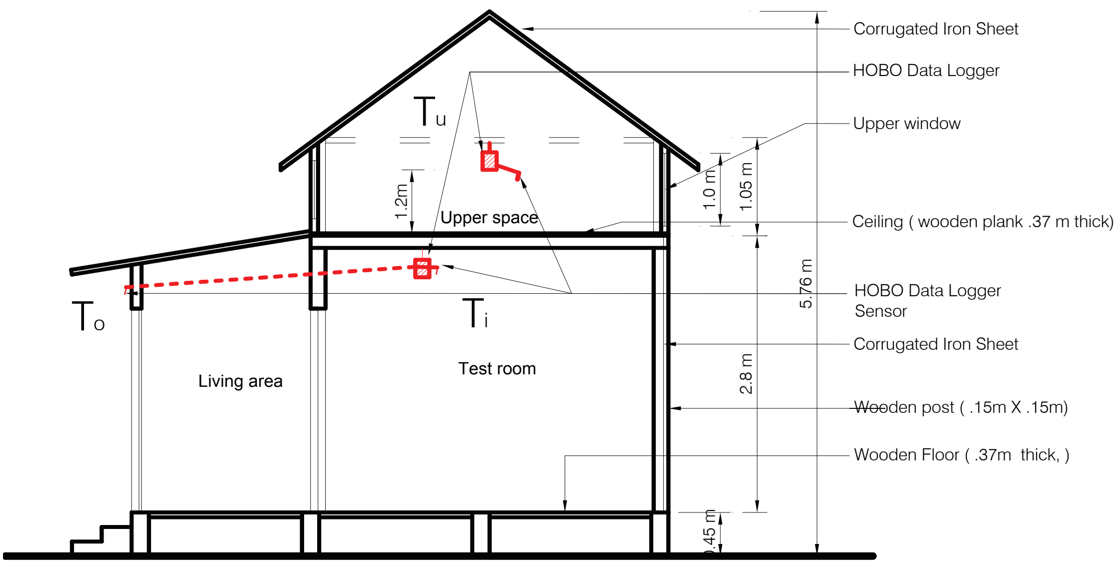

Figure 2:
Position of the Data loggers Ti = Temp indoor, To= Temp outdoor, Tu = Temp upper space

Table 2: Tabular output method of Climatic data for the test room of the traditional house

Season	Month	Date	Collected Data (Air Temperature)			Indoor Relative Humidity	Opening of window in Attic
			Indoor (Ti)	Upper Space (Tu)	Outdoor (To)		
Winter	January	10^{th} to 31^{st}	Ti	Tu	To	Rhi	0%
	February	1^{st} to 28^{th}	Ti	Tu	To	Rhi	0%
Summer	March	1^{st} to 31^{st}	Ti	Tu	To	Rhi	0%
	April	1^{st} to 30^{th}	Ti	Tu	To	Rhi	25%
	May	1^{st} to 31^{st}	Ti	Tu	To	Rhi	75%
	June	1^{st} to 20^{th}	Ti	Tu	To	Rhi	75%

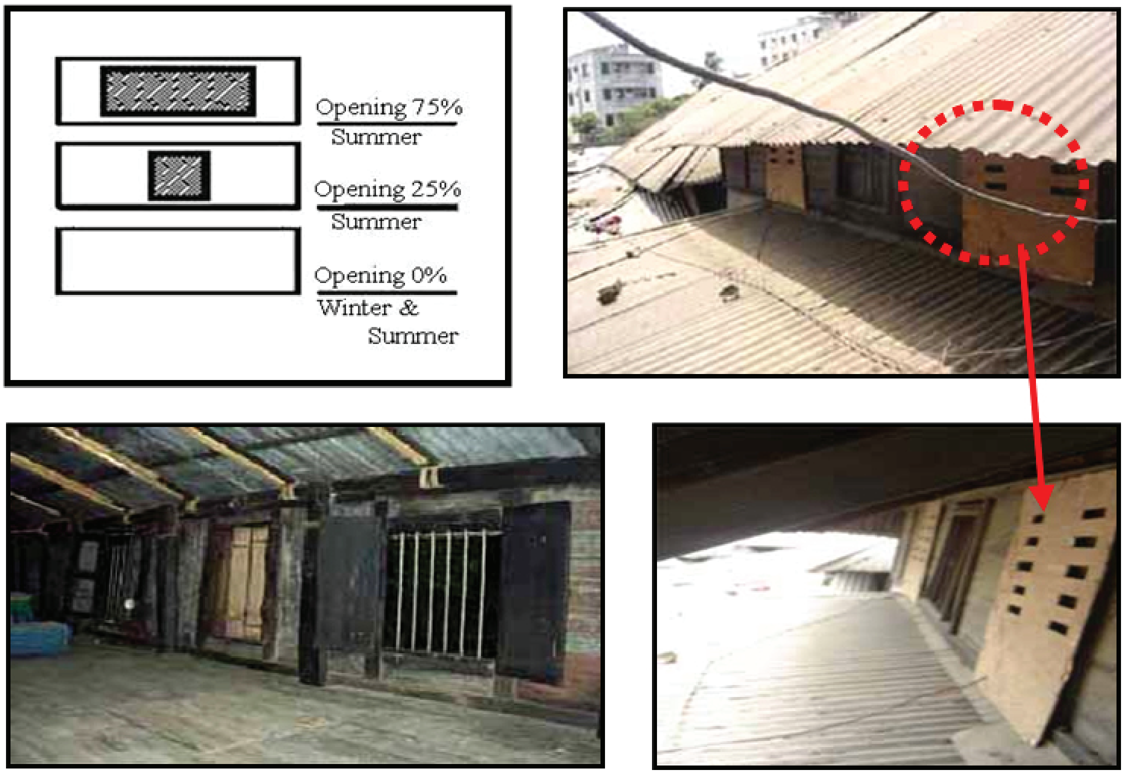

Figure 3:
Window opening 25% of the upper space during construction (right) and 75% window opening (left bottom).

4. RESULT AND ANALYSIS

In relation to the purpose of this paper, which is to discuss the influence of the design strategy on the thermal performance of the Bangladesh Traditional house, the results were analyzed by comparing the internal and external temperature of the three zones identified, namely upper space, indoor space and outdoor.

A comparative study was made to judge the influence of the upper space on the thermal performance of the traditional house, during summer and winter season with respect to thermal comfort temperature range. The performance evaluation was made on the basis of a temperature difference between indoor, outdoor and upper space (Ti= indoor temperature; To= outdoor temperature; Tu= upper space temperature) with comfort zone analysis. According to Sharma and Ali (1986) and Mallick (1994), during the winter season, comfort temperature range is 17 ºC to 32 ºC while the relative humidity range is fixed at 25% (lower limit) to 80% (upper limit), and during summer season, the comfort temperature range is between 24 ºC to 32 ºC, while relative humidity range is fixed at 50% (lower limit) to 90% (upper limit).

5. COMPARATIVE STUDY OF THERMAL PERFORMANCE OF BTH DURING WINTER AND SUMMER SEASONS WITH DIURNAL VARIATION

5a. Winter Season, with 0% Window Opening of Upper Space

Comparative study between sunrise and sunset time according to BST 6.00 AM and 6.00 PM with humidity justifies the thermal performances of the traditional house with diurnal variation during winter and summer seasons. The sunrise and sunset is 5.30 AM and 5.30 PM. After sunrise from 6.00 AM, the temperature profile starts to increase and attains maximum value at 2.00 PM to 3.00 PM (BST). After sunset from 6.00 PM the temperature starts

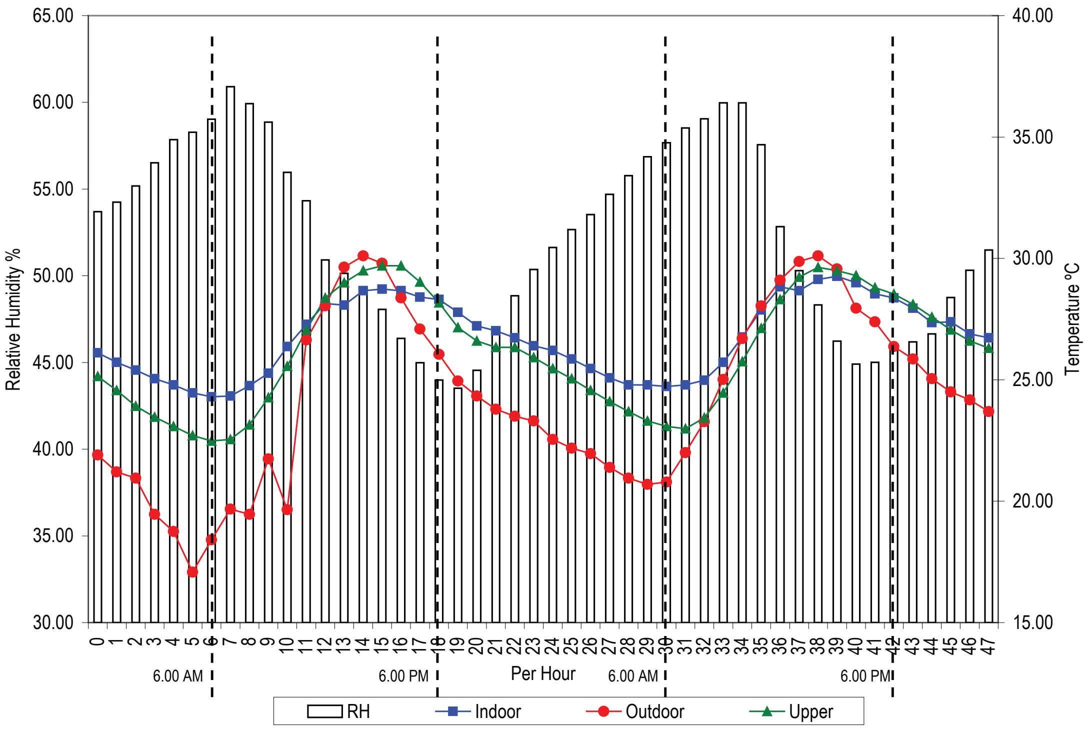

Figure 4:
Profile of temperature of indoor, outdoor and upper space air temperature with 0% opening of the upper space at 27th and 28th February 2007

to change. Therefore comparing the temperature difference between at 6.00 AM and 6.00 PM is important.

The general relationship between indoor air temperature and indoor relative humidity shows that they are inversely related the each other. Relative humidity decreases during the daytime and increases at night. The indoor minimum value of relative humidity is at 6.00 pm when the indoor space remains at the maximum temperature. So relative humidity is inversely related to temperature (figure 4).

After sunrise (6 AM to 6 PM), the outdoor temperature variation was found to be from 6.69º C to 10.01º C and within this time; the indoor temperature variation was found to be from only 3.75º C to 3.94º C. So during daytime, when outdoor temperature changes rapidly, the indoor space temperature does not change as fast because the upper space temperature profile always remains in the middle range of the outdoor and indoor space temperature profile. For day and night time the relationship of temperature difference between indoor, outdoor and upper space is Ti<Tu<To. Therefore, the upper space with closed windows is working as buffer during winter season.

5b. Summer Season, with 0% Window Opening of Upper Space

During summer months, when outdoor temperature starts to increase, the indoor and upper space air temperature also increases as high as the outdoor temperature condition or much higher when there is no opening at the upper space. Indoor temperature conditions during 9 hours after sunrise (10am to 6pm) indoor temperature is lower than outdoor temperature, and for 12 hours after sunset (6 PM to 6 AM), indoor living space is hotter than outdoor ambient environment in summer season because the upper space with closed windows is transmitting heat from the upper to the indoor space and increases the indoor temperature. So during summer season, the upper space with closed windows during the daytime

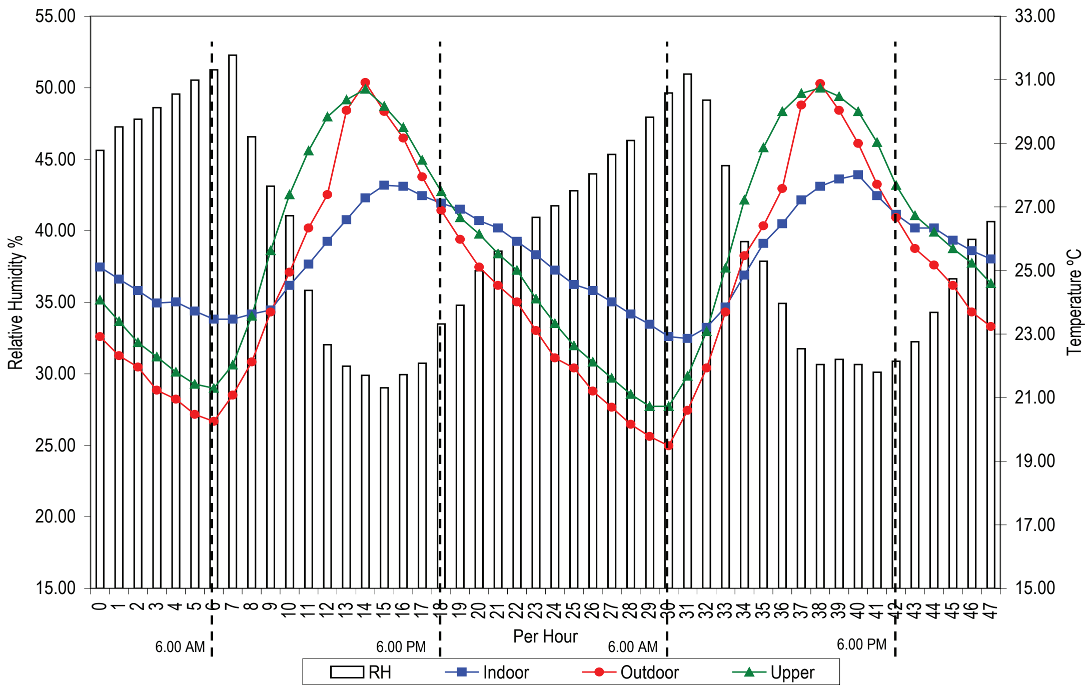

Figure 5:
Profile of temperature of indoor, outdoor and upper air temperature of the test house on 7th & 8th March with 0% Opening, 2007.

is desirable, but for night it is not preferable for indoor thermal comfort environment in the Bangladesh traditional house.

5c. Summer Season with 25% and 75% Window Opening in Upper Space

With 25% window openings, the upper space air temperature is increased by convection and radiation process during the daytime and at night, allowing long wave radiation for cooling. Therefore, window openings of the upper space are a significant factor to be considered in this research. During summer, upper space with 25% & 75% window opening during the daytime increase the upper space temperature to be higher than outdoor temperature (table 2). The convectional heat-gain by the window and direct solar radiation heat gain by C.I. sheet roof increase the air temperature in the upper space. Indoor space air temperature reached its peak after three hours later than the upper space. The upper space transmits

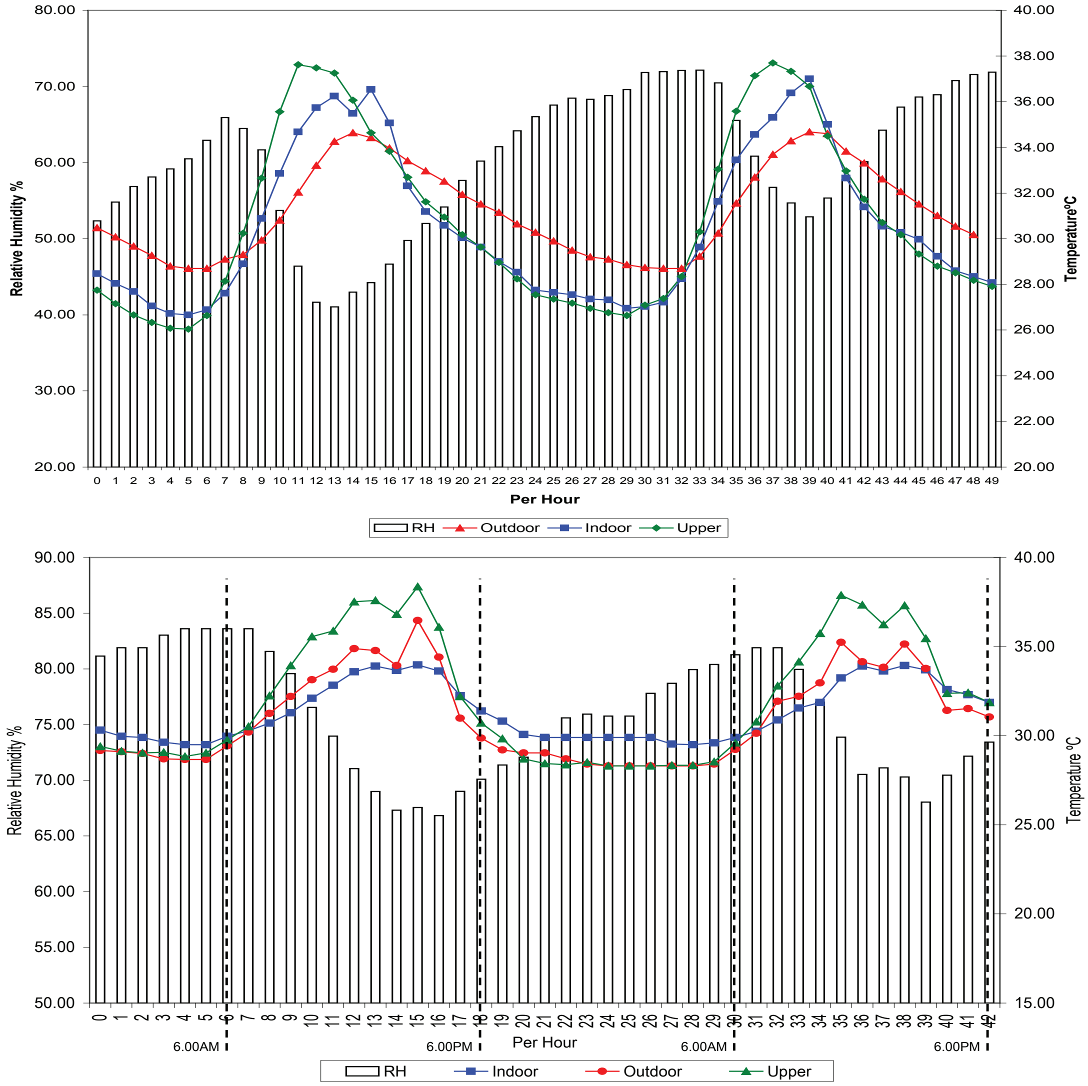

Figure 6:
Profile of temperature of indoor, outdoor and upper air temperature of the test house at 1st & 2nd April with 25% opening (Top) and 19th and 20th June 2007 with 75% opening (Bottom)

Table 3: Tabular format of duration time and hour of indoor space thermal comfort environment

Season	Date	Uncomfortable Time & hours	Window opening of upper space	Comfortable hours within 24 hours	Comfortable hours %
Winter	12 Jan.	none	0 % percent	24	100
	10 Feb.	none	0 % percent	24	100
Summer	7 Mar	none	0 % percent	24	100
	1 Apr.	12pm to 8pm (8 hours)	25 % percent	16	66
	7 May	10am to 6pm (8 hours)	75 % percent	16	66
	14 Jun.	12pm to 5pm (6 hours)	75 % percent	18	75

heat into the indoor space during the daytime, which creates an uncomfortable indoor environment. From 9 AM to 3 PM, the upper space air temperature rises and remains higher than outdoor temperature. During summer when outdoor temperature starts to increase, indoor air temperature also increases as high as the outdoor temperature condition and upper space air temperature becomes higher than outdoor temperature during the daytime after sunrise. But after sunset the upper space and outdoor temperature profile become almost the same, and they remain lower than indoor space temperature profile (figure 6). Indoor relative humidity decreases during the daytime and increases at night. The minimum value of Rh is around 3.00 PM, when the temperature of the day reached its peak and Rh is inversely related with temperature (figure 6).

During the daytime, indoor and outdoor temperature variations are almost the same, which is undesirable for indoor comfort. But at night indoor and outdoor temperature variation is at its minimum, which is suitable for a thermal comfort for indoor living spaces. 75% window opening influences the upper space through quick heat loss by convection and long wave radiation. During daytime, the upper space gains heat by convection and direct solar radiation. The indoor temperature of the traditional house exceeds the comfort temperature range for 7 hours during the day, from 10 AM to 5 PM. Before sunset, around 4 PM, indoor and upper space temperature falls below the outdoor temperature as the long wave radiation exceeds the convective heat gain.

From the information in table 2, it can be summarized that the traditional house in Bangladesh has a better ability to provide thermal indoor comfort during nighttime for both summer and winter seasons. During summer daytime, if the window opening of the upper space increases, then indoor space become uncomfortable for 7 to 8 hours starting from 10 AM until 6 PM, when maximum activity is done outside of the house. After sunset the indoor environment temperature drops within a comfortable temperature range because the upper space with open windows quickly becomes cool from conduction and convectional heat loss. During the nighttime, when people stay at home for longer periods, the indoor space temperature remains within a comfortable range, which is desirable for indoor thermal environment of BTH in the dense Dhaka city.

CONCLUSION

Traditional houses of Bangladesh reflect a deep understanding of the social and cultural response of people to the local environment and climate. The traditional houses are well suited to Bangladesh's climate through the practical use of building materials, which subsequently help to effectively increase the comfort of the living indoor environment. During the winter season, the upper space with closed windows works for heat storage, but it is not desirable in the summer season. In the summer season the upper space with 75% opening allows cross ventilation and influences indoor space to become comfortable quickly. Research results furthermore indicate that to achieve better thermal performance in Bangladesh traditional houses during winter season, windows of the upper space for both day and night time should remain closed. During the summer season, the window openings of the upper space need to be kept closed as early as possible after sunrise and open after sunset. This study concludes that the use of the upper spaces in Bangladesh traditional houses has a significant impact on the positive thermal performance and thus it makes the traditional house construction technology more efficient, comfortable and sustainable in the warm humid climate of Bangladesh.

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