COMFORTABILITY IN URBAN HOUSES OF THE TROPICS

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ABSTRACT For a house to be habitable it needs to be comfortable. In the warm humid climates interiors need to be cool for most of the year in order to be comfortable vis a vis habitable. There are many factors that contribute to the comfortable part of the overall habitability of a house particularly its aspects of design. The paper analyses the thermal conditions in ten different houses in Dhaka, Bangladeshi in representative days of the three main seasons and tries to identify design aspects that make some houses more comfortable hence habitable than others

1 Introduction

Comfortablity (not found in the dictionary) refers to comfort and habitability as one word. They are related words for a house which is not comfortable is not habitable and for a house to be habitable it is essential for it to be comfortable besides being functional, pleasant, good looking etc. Comfort here refers to thermal comfort i.e. condition of temperature, humidity and airflow. Because of the way houses are built, their location, orientation, fenestration etc. the way they modify outdoor conditions varies. Given the general weather conditions of Dhaka, the setting for this research the interior of houses need to be cooler than the exterior for most of the year, to be comfortable. While some houses are comfortable others tend to be warmer inside, much to the discomfort of its occupants.

For warm humid climates such as in Bangladesh light structures with low thermal mass is suggested with large openings for air flow. In the dense urban situation there is a general lack of air flow hence large openings are do not always serve their purpose. On the other hand it has been seen that houses in old Dhaka which have higher thermal mass are able to provide comfort to the occupants (Mallick and Huda 1995) whereas the traditional thick walled mud houses with small windows in rural areas are not as comfortable (Mallick and Ali 1996) .The paper attempts to identify the reasons why some houses have better comfort performance than others in the urban situation through the analysis of some of their varying characteristics.

2 The houses

10 rooms in 10 different houses with varying characteristics in design were selected for observations of temperature, airflow and relative humidity in Dhaka. They represent the common design typologies and the factors that were considered as influences on their thermal behaviour are:

Site, which considers the immediate environment of the house in question, whether dense, moderate or open with respect to other structures, surface qualities etc which account for thermal behavior.
Orientation takes into account the effect of solar radiation and airflow into the spaces
Exposure takes into account the exposure of the room in terms of its location above ground level. Top floors are considered to be more exposed that lower floors as there is heat gain from the roof as well.
Construction relates to the thermal mass of the houses and refers to the materials and thickness of walls roofs and ceilings

Table 1 Description of the case studies

Ref.	Room	Building	Site density	Orientations		Construction		Shading
				wall	window	walls	roof / ceiling	
1	2nd floor bedroom	3 storied office/residence	open	south	south	250 mm brick exposed exterior	150 mm r.c.c. +75mm lime	verandah
2	gr. floor bedroom	1 storied residence	dense	north	north	125 mm brick plastered	corrugated iron/bamboo	overhang
3	1st floor bedroom	2 storied residential flats	dense	south	south	125 mm brick plastered	150 mm r.c.c exposed	overhang
4	2nd floor bedroom	5 storied residential flats	moderate	east north	east north	125 mm brick plastered	150 mm r.c.c. floor above	overhang
5	1st floor bedroom	2 storied residential flats	dense	south	south	125 mmbrick plastered	150 mm r.c.c. exposed	verandah
6	2nd floor bedroom	4 storied residential flats	moderate	south west	south	125 mm brick exposed exterior	125 mm r.c.c floor above	overhang
7	gr. floor bedroom	4 storied residential flats	moderate	west south	west	375 mm brick plastered	150 mm r.c.c. floor above	none
8	gr. floor bedroom	4 storied residential flats	moderate	South east	south	375 mm brick plastered	150 mm r.c.c floor above	none
9	5th floor bedroom	6 storied residential flats	moderate	south	south	125 mm brick plastered	150 mm r.c.c + 75 mm lime	overhang
10	gr. floor bedroom	5 storied residential flats	moderate	south east	south east	250 mm brick plastered	115 mm r.c.c floor above	overhang

3 Observation periods

From the point of distinctions in temperature and humidity conditions there are 3 seasons in the year in Bangladesh (although local traditions divide the year into 6 seasons but purely from points of view of harvesting times, flora and fauna etc). The hot dry season lasts from March to May, The hot humid period from June to September and the cool period from mid October to February. Temperature measurements were made in these ten rooms in three different periods of the year, in 1992-93. Each observation period covered a 24-hour cycle with main readings at 3 hourly intervals. All observations were made on the same days to allow comparison.

Table 2 Climatic data for the observation periods

Days	Average Temperature	Swing	Seasonal Average	Seasonal Swing
April, 09 (hot and dry)	31.9°C	9.4°C	28.1°C	10.3°C
September. 07 (hot and humid)	29.8°C	5.7°C	28.3°C	5.6°C
January, 18 (cool)	16.9°C	14°C	20.7°C	12.7°C

Observations in each case measured both interior and exterior temperatures with digital max min thermometers. Spot reading of airflow and relative humidity were also taken.

4 Comfort zone for Bangladesh

Bangladesh is in the warm humid tropics and people are used to high temperatures and humidities for almost 9 months in the year. It has been suggested that comfort temperatures in such climates are higher then the notion of the comfort zone as developed in western countries (Givoni 1992, Shanma and Ali 1986). A study on the comfort requirements of subjects in Dhaka suggest temperatures between 24 and 32°C and relative humidity between 50 and 95% as being comfortable for no air movement and light summer clothing (Mallick 1995). This forms the basis for the analysis of comfort in the case studies.

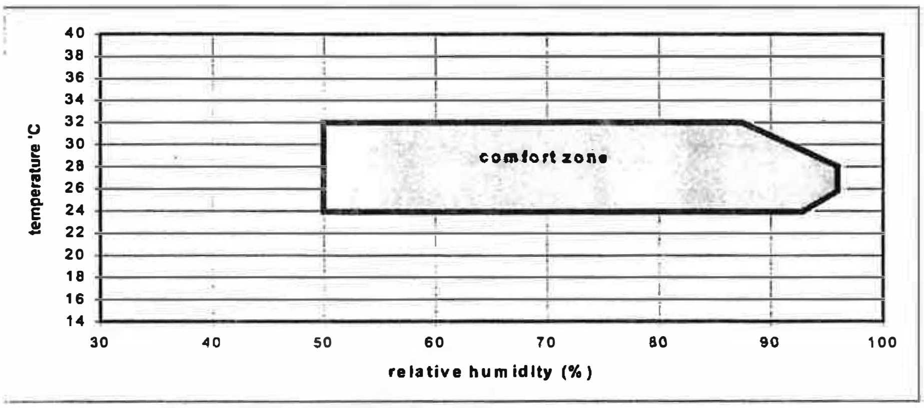

Fig.1 Suggested comfort zone for Bangladesh (after Mallick)

5 Objective of the analysis

The analysis primarily attempts to answer the question *"How do the houses feel to live in?"*. This is done through comparison of temperature data with the range of comfort temperatures applicable for Dhaka which is 24° - 32°C. The comparison of these comfort temperatures with the indoor temperatures in each house a comfort performance evaluation can be made on the basis of the following:

1. The incidence of comfort temperature indoors
2. How much do temperatures vary within the comfort range i.e. if they extend to sensations of coolness in the hot periods thus providing relief
3. Incidences of temperatures warmer than comfort and whether they occur in both the warm seasons
4. How long do these sensations of discomfort/warmth last

6 Observations on comfortability

The observations on comfort are based particularly on the conditions in the warm seasons since they account for a major portion of the year. In the cool periods all the houses are cool but the occupants are able to make subjective adjustments for comfort particularly with clothing

It can be seen from the analysis that ground floor flats that have heavier construction are the best performers in terms of comfort temperatures. Cases study reference no. 8 and 7 are both ground floor flats with relatively thicker walls and temperatures indoor are always within the comfort range in the warm seasons. Case study reference no. 9 a top floor flat is also a comfortable mainly because of the air flow it receives.

Case reference nos. 10 and 2 are uncomfortable for short periods (4-7 hours) but only in April but comfortable in the hot humid period. It is interesting to note that one is a single storied house and the other is a ground floor flat.

Case study references 1, 4 and 6 are flats on upper floors and are generally uncomfortable, up to 12 hours in April and short periods in September. This is because they are exposed to solar radiation and there is less airflow

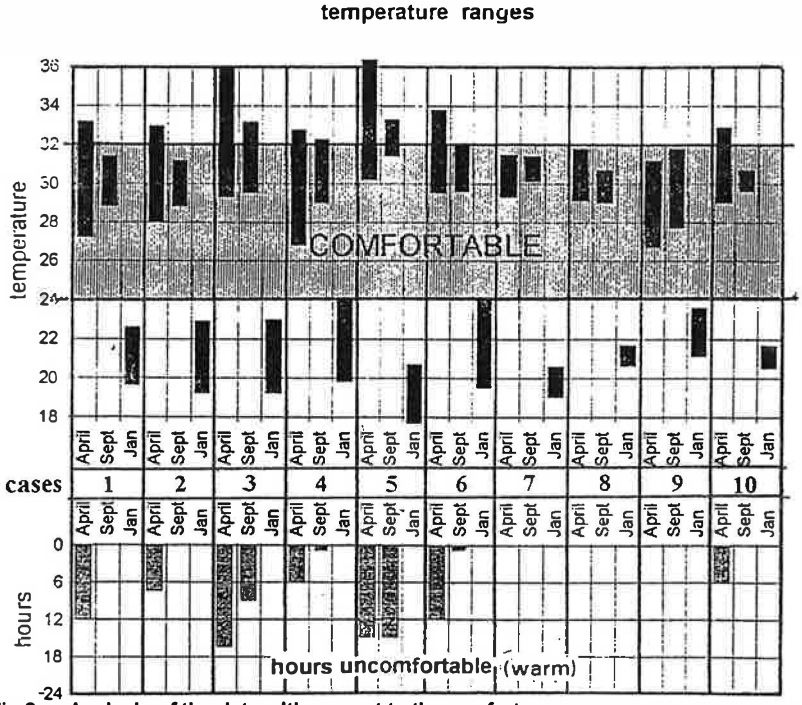

Fig.2 Analysis of the data with respect to the comfort zone

Buildings that are uncomfortable for extended periods of time in both September and April are case study reference nos. 3 and 5, both of which are upper storey flats in relatively dense neighborhoods. The roofs are flat and exposed to direct solar radiation and there is hardly any air flow . The heat accumulated during the day is also unable to escape at night because of the close proximity of buildings. It is interesting to note the surroundings of case study reference no. 2 are lowers structures with corrugated iron roofs. These roofs radiate heat which raises the temperature of the surroundings.

7 Relative humidity and comfort

Table 3 Relative humidity at location and from meteorological data

Case ref.		1	2	3	4	5	6	7	8	9	10	Met data
April	max	90	87	77	86	80	88	90	89	92	91	88
	min	48	50	42	58	50	55	49	43	50	44	50
Sept	max	85	89	82	78	75	79	79	81	88	85	89
	min	67	70	75	65	55	60	71	70	72	70	64
Jan	max	90	82	70	79	77	86	65	72	78	76	92
	min	54	44	48	40	40	50	41	55	45	43	40

Relative humidities as recorded through spot measurements at the time when temperatures were monitored show high values most of the time. The study on comfort and the resulting comfort zone for Dhaka suggests that people are able to feel comfortable at high humidities (from 50% up to 90%). Humidity measured in these buildings are within this range.

8 Air flow and comfort

Spot measurements of airflow indoors and outdoors were made in all the case studies during the observation period. Ceiling fans, though present were switched off. Since airflow varies at all times these measurements, unlike that of temperature cannot be taken to representational for the seasons. However, the observations give an indication of the effect of opening design on airflow because simultaneous readings were taken outside and inside. All houses in Dhaka have grilles or insect netting on windows, which have considerable effect on indoor airflow. Airflow in the rooms also depend on their floor location. Ground floors hardly get any airflow whereas upper floors where the surroundings are not dense have better air flow conditions.

Table 4 Air flow measurements outdoor and indoors and design of windows

Case ref.	max. indoor velocity (m/s)	max. outdoor velocity (m/s)	% of outdoor velocity	floor	opening details
1	.1	1.28	7.81%	2nd/top	grill/net
2	.01	.66	1.51%	ground	grill
3	0	.26	0%	1st/top	grill
4	.8	2.5	32%	3rd	grill
5	0	.7	0%	1st/top	grill/net
6	.7	1.2	58.33%	3rd	grill
7	0	1.4	0%	ground	grill/net
8	0	1.9	0%	ground	grill/net
9	.7	1.16	60.34%	5th/top	grill
10	.4	1.3	30.76%	ground	grill

9 Aspects of comfortablity in urban houses

From the data it is obvious that flats on the ground floor and single storey houses are better in terms of comfort that other. Ground floor flats that have thicker construction are even better. Temperatures are steady and within the comfort zone. Even though there is hardly any airflow.

Flats in upper floors are less comfortable with the exception of the ones that are on top floors in 5/6 storey buildings and have relatively open surroundings as is the case with case study reference no.9. This allows airflow and offsets the effect of heat gained form the roof slab. The conditions in such flats are comparable to ground floor flats and are probably better with the comfort possibilities that airflow has to offer.

Flats that are on upper floors (2nd or 3rd) are less likely to be comfortable particularly if they are in densely built up neighborhoods. Airflow is less and unreliable and the close proximity of building do not allow heat loss at night.

The worst situations are on top floors in lower buildings (2 stories) and which are in dense neighborhoods. They suffer from lack of airflow, inability to loose heat and also heat gained from the roof slab.

Air flow although important for comfort is unreliable because of the density of buildings and more so because of window design. Even if there is airflow outside. the possibility of it getting indoors through grilles and nets is narrow. Grilles are important in Dhaka because of security and nets to prevent insects. They account for far lesser airflow indoors than would be desirable. There are ceiling fans in most houses but they only circulate the air which is inside and sometimes warmer than outside.

Contact with ground has a positive effect on interior spaces and hence temperatures in ground floor flats or single storey buildings are lower. The absence of air flow that would have otherwise provided comfort or removed heat through convection is offset by the use of thermal mass and ground contact.

On the other hand upper floors which have possibility of air floor can be of light construction. It may therefore be beneficial to have buildings where the thickness of walls and other components diminish with height above the ground. One can imagine apartment buildings in the city where the thickness of the exterior walls decreases with the height. The lower floors that do not have the possibility of air flow rely on thermal mass and ground contact for comfort and upper floors with better air flow possibilities have a lighter structure and larger openings.

10 References

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