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Contemporary Vernacular Built form and Thermal Comfort

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Abstract—*Currently in India, the modern built form is widely used. The adaptation of a flat, concrete roof is commonly found in most parts of India without the consideration of climatic zone. Use of building materials, type of built form, orientation, ventilation play a significant role in thermal comfort. An unsatisfactory thermal environment increases the use of artificial energy such as air conditioners. The use of an air conditioner not only places stress on electrical energy, but also on global warming. Economical growth in India is propelling the common masses to use mechanical devices for cooling the buildings.*

The author conducted a field study to analyze the naturally ventilated building type constructed using rat trap bond wall masonry with filler slab and mud block with Guna tile vaulted roof for finding and comparing its suitability for thermal comfort. The selected buildings were located at Hyderabad, India. The month of June was selected to analyze thermal comfort, as it is one of the most uncomfortable months.

The observations for the harsh month of June are also compared with previous thermal comfort studies. The research study has found that the recorded average indoor temperature from 9 am to 5 pm was 32.8°C with RH 52.5% for rat-trap bond block and 33.7°C with RH 48.6% for mud block respectively. The Bio-climatic chart shows that the use of 1 m/s - 0.4 m/s air movement can contribute towards thermal comfort for rat-trap bond block. The most favourable working condition is found to be in the rat-trap bond with filler slab block compare to the mud block.

The above mentioned readings show that the use of building materials and construction techniques play a vital role in thermal comfort.

Keywords: *Bioclimatic Chart, Contemporary Vernacular, Modern Building Materials, Thermal Comfort, Traditional Building Materials, Vernacular Architectural Style*

1. INTRODUCTION

Vernacular built form had an impact of climate, context based building materials, culture and local craft. The vernacular built forms and its surrounding were complimenting each other. The emergence of modern architecture overpowered the vernacular style. After the eighteenth century, modern architecture style became more prominent but introduced few issues such as thermal comfort.

Architects such as Geoffrey Bawa, Charles Correa, B. V. Doshi etc. understood the need and concern about the thermal environment. They designed buildings keeping in mind not only thermal environment but also the local context. In their designs, they incorporated both local as well as modern building materials and construction techniques.

In this paper, the focus was to study thermal comfort, building materials and construction techniques of a single story naturally ventilated building blocks located in city of Hyderabad, India. These building blocks were constructed using both locally available and modern building materials. The building materials used for these built forms were mud bricks, cement mortar, concrete, Guna clay tiles & Mangalore clay tiles. The city of Hyderabad, India was chosen for the study as it falls under the composite climatic zone like most parts of India. The harsh and uncomfortable month of June 2014 was selected for the study.

2. CHARACTERISTICS OF LOCAL CLIMATE

Hyderabad is grouped under the composite climatic zone. The relative humidity is low in dry periods and high in wet periods. Generally, composite regions experience higher humidity levels during the monsoons than hot and dry periods.

The summer months from March to June are hot and humid, with average highs in the mid 30°C with maximum temperatures often exceeding 40°C between the months of April and June. May is the hottest month with daily temperatures ranging from 26 to 38.8°C. The annual mean temperature is 26 °C and monthly mean temperatures are 21 to 32 °C. [7]

3. THERMAL COMFORT

The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) defines thermal comfort for a person as “that condition of mind which expressed satisfaction with the thermal environment”. [3]

Human thermal comfort is the state of mind that expresses satisfaction with the surrounding environment and was first explored by Ole Fanger in the 1970s. Fanger's studies of thermal comfort found that not everyone is satisfied by a particular set of environmental conditions, but in ranges of conditions about 80% express satisfaction.

There are six parameters i.e. activity, clothing, air temperature, humidity, air velocity and radiation. that govern the thermal comfort. While activity and clothing are specific to an individual, air temperature, humidity, air velocity and radiation are the properties of the environment. There are several other minor parameters like health, light etc. which also influence the thermal comfort.

4. BUILDING MATERIALS AND HEAT TRANSFER

Conduction, convection, radiation and evaporation/condensation are the four ways of the heat transfer in buildings as shown in Fig.1. Givoni (1976) reports that during the process of heat entry through the building, the mode of heat transfer may change. For example, solar energy reaches the wall surface in the form of radiation, absorbed at the external surfaces and flows across the wall material by conduction.

The properties of materials that affect the rate of heat transfer through the building, are thermal conductivity, resistance and transmittance, surface characteristics, surface convective coefficient, heat capacity and transparency to radiation of different wavelength and as a result, the indoor thermal conductions and comfort of the occupants (Givoni, 1976).

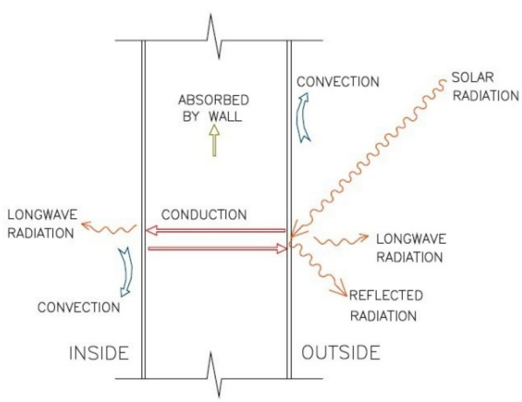

Fig. 1: Heat transfer processes occurring in a wall

(Source – Ministry of New & Renewable Energy of India)

Givoni (1976) points out that the envelope of a building not only separates it from the external environment but also prevents climatic elements to affect the building directly. Three types of building materials can be used to build this envelop which are: opaque, transparent and translucent. He further points out that heat may enter the buildings - firstly, through transparent and translucent materials, open windows and secondly, through the modifying influence of the rest of the building materials. Then internal thermal comfort conditions may be affected both directly and dependent on the properties of the materials by the external temperature and humidity.

Humphreys was the first to show the strength of the relationship between outdoor temperature and the comfort temperature indoors, particularly for buildings that are neither heated nor cooled. [6]

5. RESEARCH STUDY SAMPLE

The samples selected for the study were naturally ventilated building blocks having similar volume. The first selected building block was constructed using filler slab & exposed rat-trap bond masonry construction techniques, and the other block was constructed using exposed mud block masonry & conical clay tiles vaulted roof, located at Rural Technology Park (RTP), National Institute of Rural Development (NIRD), Hyderabad, India (Fig. 2). The main function of these building blocks was office use.

The rat-trap bond technique was developed by an architect Laurie Baker. The bricks are placed on their edges in 1:4 cement mortar and after the first layer of bricks is placed, a gap is left between the bricks in the remaining courses. Compared to a 230mm thick solid brick wall this technique has the advantage as the number of bricks required to build this wall is reduced by 25% and consequently, the quantity of cement mortar needed is less. [2]

Filler Slab & Rat-Trap Bond	Mud Block & Guna Tile Roof

Fig. 2: Rat-Trap Bond with Filler Slab & Mud Block with Guna Tile Roof - Rural Technology Park, NIRD Hyderabad India
(Source - Author)

The first selected building block was constructed using filler slab construction technique. To reduce the load of the filler slab, locally available building materials i.e. Mangalore tiles were used on the tension side. To transmit the natural light, the glass material was used as skylight replacing some of the roof tiles. This filler slab composition did not compromise with its structural strength. As cement concrete was expensive, this composition resulted in an economic structure.

For the second selected sample, the roof was constructed using vault system covered with conical tiles made out of clay inserted into one another. This building was constructed using locally available earth, eco-friendly fly ash bricks for the columns with vertical bars, mud blocks for the walls, IPS flooring with colored oxide, bamboo panelled door and window shutters.

Cement mortar 1:3 was applied to cover the conical clay tiles. The roof vault space creates volume and provides hot air pockets and adjacent cement grill ventilators were used to release the hot air. The advantage of vault roof form is that it catches less solar radiation compared to flat roofs which helps in reducing the heat load inside the building. [2]

6. METHODOLOGY

For the selected sample building blocks, the objective was to determine the behaviour of structure in terms of thermal comfort for uncomfortable month of June, as this is one of the hot and the uncomfortable months according to the past study [8].

To achieve the objective, two data loggers were placed to record the dry bulb temperature and relative humidity at every half an hour interval for the month of June 2014. One data-logger was placed inside the building block on the west side, as it has been proven from the previous study that the intensity of solar radiation is more on the east & west side in summer months [6]. Another data-logger was placed outside, in the vicinity of buildings, to record the ambient temperature and relative humidity. Wind speed and wind direction were recorded from the nearby airport.

The recorded temperature and relative humidity data was then analyzed using a Bioclimatic chart [14] and past thermal comfort research studies by other researchers and the National Building Code of India [8].

7. PREVIOUS THERMAL COMFORT STUDIES

Many researchers throughout the world have researched in the field of human thermal comfort studies. As the thermal comfort range can vary at different places, there is a need to establish a localized thermal comfort standard based on latitude, altitude, geography and climate of a place. It may be noted that the climatic conditions for equatorial highland regions tend to be generally the same all year round (Ogoli, 2000). [9]

A study conducted by Indian researcher Madhavi Indraganti under "free-running", or natural or passive solar conditions at Hyderabad, India showed that the comfort range of temperature in Hyderabad, India has a lower limit of 26 °C and a upper limit of 32.5 °C.[5]

The National Building Code of India specifies two narrow ranges of thermal comfort temperature i.e. summer (23–26 °C) and winter (21–23 °C). [5]

According to J. Fergus Nicol and Michael A Humphreys, the thermal comfort range was found to be between 20 °C and 30 °C as shown in Fig.4 & 5. From Fig. 5 it can be noticed that on many occasions the subjects recorded no discomfort. With a continually changing indoor temperature and comfort temperature Pakistani buildings were found comfortable at temperatures ranging between 20 and 30 with no cooling apart from fans (Nicole el al 1999). [4]

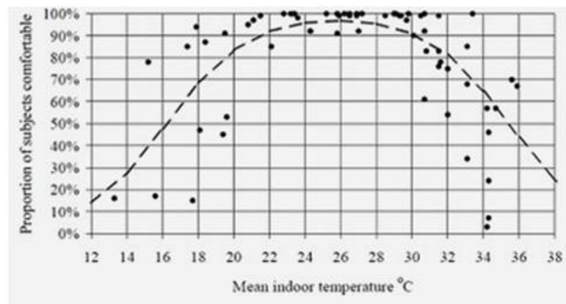

Fig. 4: Proportion of office workers comfortable at different indoor temperatures in Islamabad, Pakistan. [4]

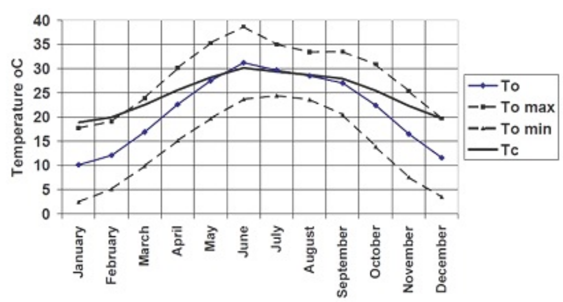

Fig. 5: Seasonal changes in mean comfort temperature (To), in Islamabad, Pakistan and its relation to mean daily maximum, minimum, and mean outdoor temperatures. [4]

Humphreys and Nicol (2000) have shown that for free-running buildings, the relationship between comfort temperature Tc and outdoor temperature To is remarkably stable.

J. Fergus Nicol and Michael A Humphreys, derived the equation for thermal comfort temperature (Tc) as

$$Tc = 13.5 + 0.54 * To$$

Where To is the monthly mean of the outdoor air temperature. [4]

8. OBSERVATIONS & ANALYSIS

The indoor dry bulb temperature, outdoor dry bulb temperature, wind speed and relative humidity data was collected for the month of June 2014 for rat-trap bond block and for mud block. The data was collected every 30 minutes and the average was computed for each day (Fig.6). The data was recorded for the time 9am to 5pm. The selected time period is chosen to comprehend the behaviour of built form for thermal comfort. The main prevailing wind direction was found to be South-West side. The average wind speed was 11.4 mph for the month of June 2014.

As shown in Fig. 6, the average indoor and outdoor temperatures and relative humidity are plotted on the primary axis and secondary axis respectively.

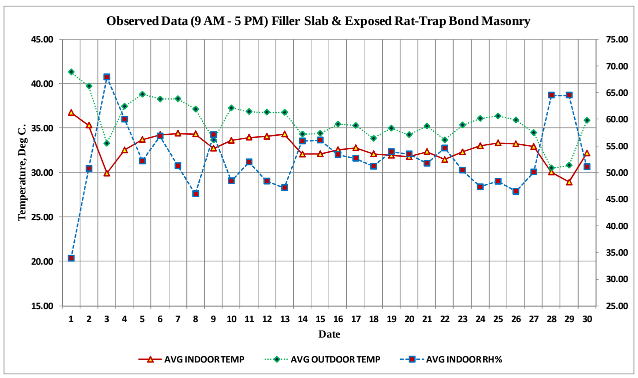

Fig. 6: June 2014 - Observed Data - Filler Slab & Rat-Trap Bond Masonry

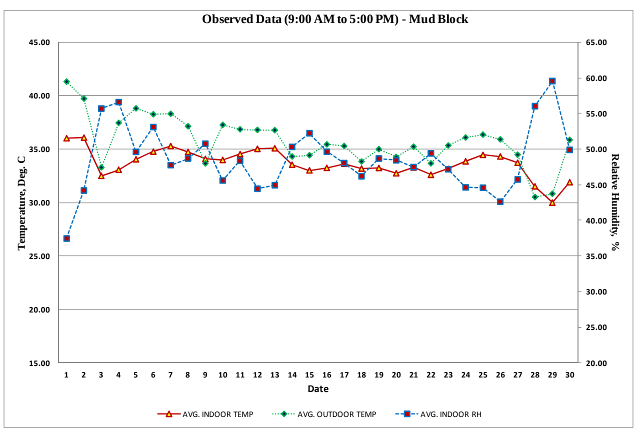

Fig. 7: June 2014 - Observed Data - Mud Block

It is observed that in the day-time graph i.e. 9 am to 5 pm, the indoor average temperature is lower than the average outdoor temperature. It is found that the variables, indoor temperature and humidity are comparatively low in rat -trap bond than mud block. At the rat-trap bond block cross ventilation takes place due to availability of brick jali. The continuous airflow produces the favourable indoor condition especially in monsoon high humidity period. The diurnal temperature difference in rat-trap bond is 12.1ºC and in mud block is 8.9ºC . The conclusion that can be drawn from these recordings is that due to the high thermal capacity of building materials and air gap between two bricks which acts as an insulator, the thermal lag has been achieved better in the rat-trap bond block.

9. BIOCLIMATIC CHART ANALYSIS

9.1 Comfort Zone Using Bioclimatic Chart

Bioclimatic chart is a simple but effective tool for analysing the climate of a particular place during different periods. Fig. 8 & Table 1 illustrates a ‘Comfort Zone’ of human comfort based on ambient temperature and humidity. This chart for men at sedentary work - wearing 1 clo. clothing - in warm climates (Original by V Olgyay in British units - some values revised according to Australian CEBS findings) [10]. On the chart, dry bulb temperature is used as the ordinate, and relative humidity as the abscissa. Based on the dry bulb temperature and humidity of a place, one can locate a point on the chart. Based on the position of this point, bioclimatic chart can give ready information about the requirements of comfort at a particular period. Based on the comfort zone of the bioclimatic chart, decisions can be taken for design of buildings. [11]

In this research study, for the month of June 2014, the average of the daily maximum temperature was calculated and matched with the average of the minimum daily absolute humidity to obtain a point (Tmax, Wmin). Likewise, the average of the daily minimum temperature was matched with that of the average daily maximum absolute humidity to obtain a point (Tmin, Wmax). The placement of the line segment connecting the two points determines the proper passive cooling strategy for that month. [9]

The values shown in Table 1 were calculated to plot the line segments on the bioclimatic chart.

Table 1: Calculation of Average Daily Temperature & Relative Humidity

	AVG MAX TEMP °C	AVG MIN RH%	AVG MIN TEMP °C	AVG MAX RH%
9am-5pm (Rat-Trap Bond Block)	34.68	46.47	30.09	60.91
9am-5pm (Mud Block)	37.9	34.7	29.1	62.6

The position of line segments on the bioclimatic chart are just above the thermal comfort zone. This indicates that air movement of 0.1 m/s to 1 m/s is required to achieve the thermal comfort for rat-trap bond block. For mud block air movement with air coolers are recommended.

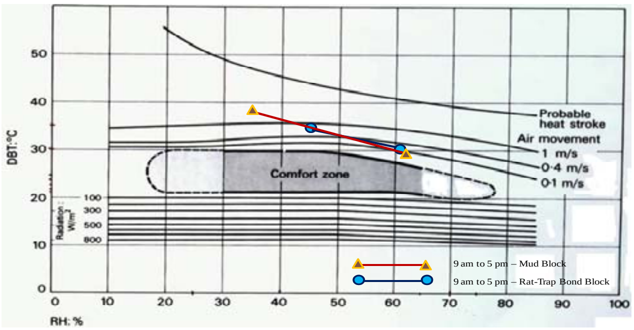

Fig. 8: Bioclimatic Chart - Rat-trap Bond & Filler Slab, June 2014

9.2 Analysis with previous thermal comfort studies and building code

The data recorded for research for the month of June 2014 was analyzed and compared with a research conducted by Madhavi Indraganti (2010), National Building Code of India (2005) and research conducted by J. Fergus Nicol and Michael A. Humphreys at Islamabad, Pakistan.

The study conducted by Indian researcher Madhavi Indraganti showed the comfort range of temperature in Hyderabad, India has a lower limit of 26 °C and a upper limit of 32.5 °C [4] and the National Building Code of India specifies two narrow ranges of thermal comfort temperature i.e. summer (23–26 °C) and winter (21–23 °C). [5]

In this research study, the average outdoor temperature for the month of June was found to be 31.1 °C. Based on the formula developed Nicol & Humphreys,[4] the value of thermal comfort temperature is found to be 30.29 °C as calculated below.

$$Tc = 13.5 + (0.54 * 31.1)$$

$$Tc = 30.29\ °C$$

Fig. 9 & 10 shows the comparison of data with previous thermal comfort research studies.

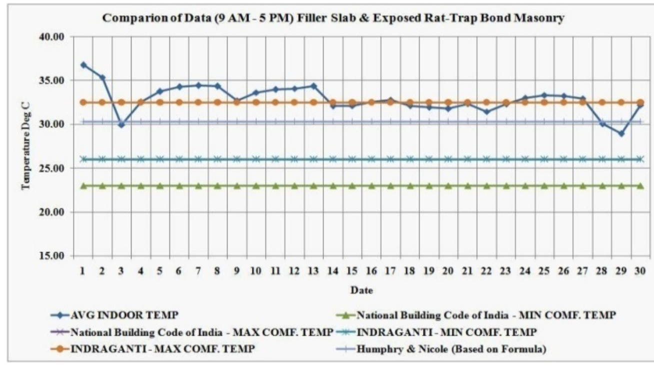

Fig. 9: June 2014 - Comparison of Data with Comfortable Temperature Range - 9 am to 5 pm - Rat-Trap Block

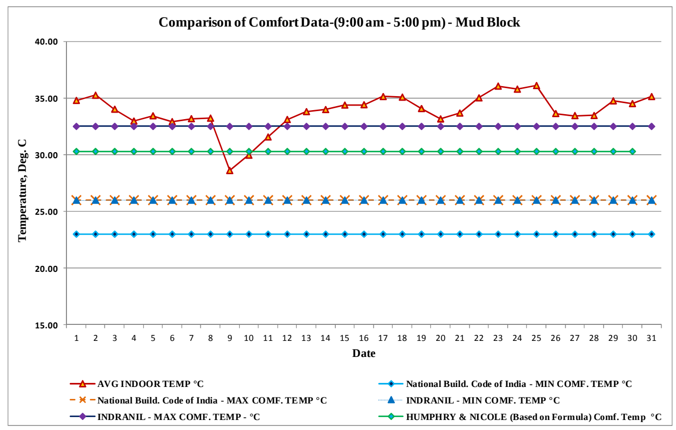

Fig. 30: June 2014 - Comparison of Data with Comfortable Temperature Range - 9am - 5pm - Mud Block

The research study conducted by various researchers mentioned the comfort temperature according to their study. Table 2 summarises the comfort temperatures derived from the previous studies and shows the observed average indoor temperature for both the building blocks.

Table 2: Thermal Comfort Temperatures, Tc

***Observed Operative Avg. Temp (This research, Hyderabad, India)* Rat-Trap Bond ºC**	**Observed Operative Avg. Temp (This research, Hyderabad, India) Mud Block ºC**	***National Build. Code of India - 2005* ºC**	***Madhavi Indraganti - Study on Thermal Comfort-Hyderabad, India ºC***	***Humphreys and Nicol - Islamabad, Pakistan* ºC**
31.7 - 32.8	33.2 - 33.8	23 - 26	26 - 32.5	30.29

From Table 2, it can be noticed that the observed operative average temperature in the research sample is 31.7 - 32.8 ºC for rat-trap bond block and 33.2 - 33.8 ºC for mud block. These readings are very close to research thermal comfort readings found by other researchers.

It is observed that during the month of June 2014, the average indoor temperature of the selected building block falls near the upper comfort limit 32.5 ºC defined by Indraganti [5] who had conducted the research at the same place i.e. Hyderabad, India.

The average indoor temperature in this study also falls near the thermal comfort range defined by J. Fergus Nicol and Michael A Humphreys which was found to be the between 20 °C and 30 °C. [4]

However, it is not close to the range mentioned in National Building Code of India. As there is very little thermal comfort research in India other than by a few [5], thermal comfort standards are not defined in Indian Codes. For all climate and building types, the National Building Code of India specifies the use of two narrow ranges of temperature: summer (23–26 °C) and winter (21–23 °C). These standards are based on ASHRAE standards, which are not validated through empirical studies on local subjects. [1]

10. CONCLUSION

From the research study, it is found that the building material is one of the important building components that play a vital role in bringing thermal comfort. In this research sample study, the working conditions are more favourable because of the use of rat-trap bond, filler slab and brick screen (jali). The mud block can also define favourable work conditions if air coolers are introduced. Buildings that are used for a short period, especially in the forenoons or afternoons designed with the construction technique of rat-trap bond, filler slab, mud blocks are simple, cost-effective techniques with strong insulation properties best for thermal comfort. These construction techniques need popularity not only in rural areas but also in urban areas.

Traditional building materials in conjunction with modern building materials achieve thermal comfort and produce excellent architectural style.

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