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Material Thermal Performance Comparison Between The Tomb Of Mohammad Ghaus Heritage Building And A Modern Style Dwelling In Madhya Pradesh

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ABSTRACT

Building envelope not only provides us the protection from outside environment but also provides the necessary thermal comfort required for anyone residing inside it. It is observed that the natural cooling arrangements provided in the ancient buildings have a great influence on the thermal comfort inside the buildings. This type of arrangement of thermal comfort is not considered while designing new structures. So, the energy consumption in modern structure is more for the same thermal comfort as in ancient structures. Inside humidity, room temperature, mean surface temperatures, air variation ratio and lighting are some factors affecting thermal comfort. The materials such as cement and steel used in modern constructions are highly durable but not energy efficient. Hence necessary balance must therefore be achieved between energy efficiency and durability of modern buildings. Against this background, the paper presents a comparison of the thermal comfort inside the Tomb of Mohammad Ghaus heritage building and a modern style dwelling estimated around 10 years old. The average inside temperature of modern and heritage building was 32.65°C and 26.96°C respectively while the average outside temperature during observation period is 29.96°C. The average inside relative humidity of modern and heritage building was 61.73% and 68.93% respectively. As the heritage building was found cooler than the modern building, the study suggests that the cooling arrangement provided in the ancient buildings is imitable and beneficial to be incorporated in modern buildings.

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1. Introduction

Nowa day, a role of an architect and engineers are increasing in the construction sector. While constructing a building, along with its design various factors need to be considered like its cost, environmental impact, aesthetic look etc. The building construction involves various steps from its preliminary designs to final construction. The various building systems put some restrictions on one another as they are inter-related. Each system has various sub-systems like designing building from environmental point of view includes consideration of thermal, audio and video sub-systems. The paper is about the thermal consideration while designing building from environmental point of view.

With increasing population, the energy reserves are depleting at a very faster rate. The buildings need to be designed in a way that it consumes lesser energy produced from various conventional energy resources. The effort is made toward utilization of natural resources as much as possible. As the ancient structures are designed in such a way that there is no need of AC or cooler or fan for creating thermally comfortable environment. They have inbuilt feature for providing thermal comfort. But in modern structure, due to lack of awareness the people are not considering about climatic design. The buildings can be made energy efficient by adopting solar passive arrangements as per the climatic condition of a particular location (Zinzi and Santamouris, 2019). Bano and Kamal (2016) presented the review showing the impact of building envelope on heating and cooling load of various office building in India under different climatic zones.

Sustainability is considering environmental, economic and social requirement all together while designing a building. All these aspects are already considered in ancient buildings but now in modern structures the building regulation mostly focuses on environmental impact of building especially reducing the usage of fossil fuel. The steps are taken towards the reduction of CO_2 generation from construction of building to its daily use. The ancient structures were already sustainable and net zero energy buildings. As for the transportation of ancient building material, mostly man or animals were used, emitting zero carbon. Even for lightning, building heating and cooking, the biomass is used which is in itself a sustainable source of energy. The wind and water (Hydro) energy were also used where available either for transportation purpose or for timber making. The heritage buildings can be preserved or can be reused by upgrading it thermally as per the principles of building conservation and its sustainability. In many cases it is observed that by proper adoption and reuse, the new structure formed is of high-quality architecture.

The paper compares the thermal comfort in modern and heritage building (Tomb of Mohammad Ghaus) in Gwalior, India and the techniques that can be adopted from ancient building for creating better thermal comfort in modern buildings with less energy consumption. The inside temperature and humidity inside the heritage building was compared with the inside temperature and humidity of modern style building. The difference between the two is shown by graphs plotted.

2. Literature Review

2.1 Researches on Traditional Buildings

Hatamipour and Abedi (2008) described the natural cooling arrangement in ancient Bushehr architecture in hot and humid region of Iran. These arrangements protect the people from hot summer climate for a long time without using any electric air conditioner. The arrangements made for natural cooling are: properly insulated roof sand walls, smaller windows and use of light color in walls for lesser heat gain, building orientation along direction of wind, using wooden sunshades and high thermal mass (heavy walls).

Traditional and modern architecture of Ghana is compared by Abdul Manah Dauda (2016). Maximum temperature inside the modern building was 37°C while in ancient building it was 35°C. In traditional building, the mean room temperature was found 4-5°C less than modern buildings. This is due to roof made of thatch providing proper ventilation and pores in them allow hot air to escape through it. While in modern structure, the metal sheet used creates thermal discomfort as it increases the room air temperature by absorbing the inside heat and transferring it to the air inside.

In Nepal, Susanne Bodach et al. (2014) studied about the climate responsive vernacular architecture, its designed construction strategies. After the study it was found that the thermal comfort in the vernacular architecture was due to higher thermal mass, overhanging roof preventing sunrays to enter directly inside the building, solar natural heating and cooling arrangement, medium sized windows etc. It was recommended to use this technique in modern structure also.

In Bhopal, Megha Jain and Singh SP (2013) reported the passive solar techniques used in the Gohar Mahal (Heritage Building). The building was constructed in 1820 having incorporated passive solar arrangements. The inside temperature, air velocity and humidity inside the Gohar Mahal were observed and compared with the outdoor condition. In summer season the inside temperature was below 26°C which is due to proper envelope design and high thermal mass that helps in providing better thermal comfort and stabilizes the inside temperature.

Manoj Kumar Singh et al. (2014) optimize the design of vernacular building in North-East India by using TRNSYS 17. The 3 types of construction and 8 possible orientations of 3D models were used for optimizing design. Various parameters like window to wall ratio, thermo-physical properties, ventilation, shading, heat load inside the building, its orientation and false ceiling types were considered for optimizing design. The energy consumption in vernacular structure has been found increasing in recent years. With the objective of reducing thermal discomfort, he suggested that use of ventilator and windows with large opening promotes cross ventilation. Double glazed windows and proper shading improves the inside thermal comfort. The vernacular structure was found more comfortable in pre-summer and pre-winter season.

Usha Bajpai and Sachin Gupta (2015) reported the solar passive arrangement provided in Avadh Architectural Buildings, Lucknow, India. Tomb of building had various feature aiding passive concept like curved and high roof, thick wall, proper openings and light-colored exterior preventing heat transfer inside the building. The building has a height of around 10 m which is suitable for proper natural convection. Due to large wall thickness, the U-value of wall was also high.

Manoj kumar singh et al. (2010) carried out the thermal performance evaluation vernacular buildings of North-Eastern part of India. For study, 50 vernacular houses with 100 residents were taken. The study was done in the months of January (winter), April (pre-summer), July (summer/monsoon) and

October (pre-winter). The doors, windows and ventilators cover about 50 % of area. Window to wall ratio was 0.216 and heat transfer lags by 5-6 hours which shows higher insulation. Inside house temperature swing by maximum of 10°C, that is noble for naturally ventilated buildings but the inside day lighting was found insufficient.

During retrofication of traditional building of Sugganahalli near Bangalore, Praseeda et al. (2014) studied the effect of material change on Embodied Energy (EE) and Operational Energy (OE). Comfort standards by ASHRAE and TSI model by Sharma and Ali were used. It was observed that the traditional buildings with passive arrangements consume lesser operational energy in extreme climatic change also. The change in material will increase the embodied energy of the building.

Kranti Kumar Mynani (2013) studied the effect of providing courtyards in traditional buildings in Athangudi village, Tamilnadu, India. It was observed that the courtyard in the houses provides the cool environment inside the house during daytime. He suggested making the courtyard a part of modern building so as to have a better living condition.

Some of the previous studies undergone in traditional buildings in various part of the world having different climatic condition are shown in Table 1.

Table 1 Observations from various Traditional buildings

S. No.	Buildings/Structures	Building features	Climate
1.	Bushehr architecture	• Properly insulated walls and roofs, light coloured surfaces reduces heat gain through walls. • Overhung shading, wooden sunshades and using trees for shading of buildings. • High roofed buildings with sufficient windows.	Hot and humid
2.	James town light house	The thatched roof having pores provides proper ventilation and allows hot air to escape through it.	Tropical
3.	Vernacular Houses	Courtyards and semi-shaded open spaces like verandas and balconies provide cool environment in summer.	Subtropical
4.	Gohar Mahal	Includes landscaping, water bodies, orientation, site features, open spaces and envelope design.	Subtropical
5.	Vernacular buildings	• Windows and ventilators with large openings will promote cross ventilation. • Double glazed window and proper shading elements improves indoor thermal conditions	Warm and humid climate
6.	Avadh Architectural buildings	• Due to very thick wall, U-Value of the wall was low. • Usage of water and landscaping created the micro climate inside and around the building.	Warm and humid climate
7.	Hangudi village Buildings	Courtyard provides the cool inside environment during daytime.	Agro climatic zone
8.	Sugganahalli Building	• Passive arrangements consume lesser operational energy in extreme climatic change. • Embodied energy increases due to change in material. • ASHRAE comfort standards and TSI model were used.	Tropical savanna climate
9.	Jack Arch (JA)	• Self-shading by arches reduces solar heat gain. • Brick roof reduces solar heat gain as bricks have low thermal conductivity than concrete.	

2.2 Researches on Modern Buildings

Some of the previous studies undergone in modern buildings in various part of the world having different climatic condition are shown in Table 2

Table 2 Observations from various modern buildings

S. No.	Buildings/Structures	Building features	Climate
1.	Western Cape (South Africa)	• Used self-shaded courts, higher ceiling, wall and roof with high thermal mass. • East-west orientation with North light roof, elongated north and south fronts for receiving day-light and natural ventilation.	Subtropical
2.	New Assist housing in Egypt	As per bioclimatic chart for summer season, data measured was found within the boundaries of natural ventilation and evaporative cooling.	Tropical
3.	Modern low-cost housing units at Kanyakumari, Thirunelveli and Madurai Districts	Study shows that houses at these three locations were thermally uncomfortable. Various solar passive arrangements have been recommended to increase thermal comfort.	Tropical

For residential buildings in Western Cape, South Africa, sustainable solutions are suggested by Fahimeh Foudazi and Mugendi M Rithaa (2013). Solar passive cooling arrangement will provide the better thermal comfort and reduces consumption of electricity. It was suggested to use self-shaded courts, higher ceiling, wall and roof with high thermal mass, East-west orientation, elongated north and south facades for daylight and natural ventilation, domed and light-colored roof with vents, landscaping and geothermal cooling.

The indoor environments and thermal comfort in newly assisted houses in Egypt was studied by AMR Sayed et al. (2013). For study during summer season, psychometric charts by ASHRAE standard 55 and Adaptive Comfort Standard (ACS) were used. The maximum and minimum outside temperature was 43°C and 27°C with corresponding relative humidity of 4% and 40% respectively. The inside temperature varies from 31°C to 40°C for different ventilation arrangements.

The effect of glazing tile, window to wall ratio, courtyard and atrium in the performance of building is analyzed by Tofigh Tabesh and Begum Sertyesilisik (2015 & 2016). It was observed that the courtyard and atrium in buildings results in energy saving in all three climatic conditions. In summer, courtyard with larger openings was found suitable while in winter atrium made is best.

Thermal performance of modern low-cost housing units was investigated by Vincent Jayaseelan V and Ganapathy C (2007) in three different locations of India (Kanyakumari, Thirunelveli and Madurai Districts). Tropical summer index (TSI) by Sharma and Ali 1986, was found out and compared with comfort temperature given by Nicol F et. al. 1994. Study shows that houses at these three locations were thermally uncomfortable. Various solar passive arrangements have been suggested to improve thermal comfort.

2.3 Comparison of Traditional and Modern Buildings

Comparison of modern and traditional architecture in North Sulawesi-Indonesia is done by Sangkertadi et al. (2008). For study, ten modern and ten traditional buildings with 60 residents has been taken as sample. The residents feel comfortable at temperature maximum upto 29°C and humidity upto 60 % with air flowing at slow speed.

Thermal performance of modern and traditional architecture in Thailand had been compared by Paruj Antarikananda et al. (2006) using ECOTECT simulation model. The modern structure consists of bricks walls, concrete floor and roof, plasterboard ceiling and tiles over roof while the traditional buildings in Thailand consist of high roof, adequate walls and windows and central terrace. The air conditioning in modern buildings is done using mechanical devices which results in more energy consumption and affecting the environment. It was observed that the traditional structures using passive cooling techniques are more responsive to extreme climate condition.
The modern low-income housing built at Sarawak; East Malaysia was found thermally uncomfortable as reported by Tinker JA et al. (2004). The traditional Malaysian houses were designed as per the climate condition and provide better thermal comfort inside the house. Parameters affecting thermal comfort are measured in both traditional as well as in modern building. Comfort level is investigated by using CFD and corrected effective temperature index method. They observed that traditional structures are more comfortable than modern ones. They suggested using ventilation with grills for proper air flow and better thermal comfort in modern buildings.

In Kerala, questionnaire survey had been done by Dilli AS et al. (2010 & 2011) from the peoples living in traditional and modern buildings. The survey result shows that 70% peoples feels comfortable in traditional buildings in all climatic conditions while only 20% feels comfortable in modern buildings in summer season.

Subramanian C.V. et al. (2017) observed that the natural cooling arrangement in ancient building provides more thermal comfort than modern building in all seasons. He suggested employing the passive techniques of ancient structure in modern style buildings. People feel more comfortable with a less electricity consumption and air conditioning, due to integrating with customized strategies as per local climatic conditions. This phenomenon is an attempt towards Energy efficient green buildings for future.

Priya Shanthi R et al. (2012) conclude that ancient building is thermally comfortable than Modern style buildings for the similar environment. The inside temperature is higher in modern style building in comparison to inside temperature of ancient buildings with the same outside temperature for both buildings. The evaporative cooling phenomena is the main causes for significant temperature variation between inside and outside temperatures of ancient building in summer take places in stone based ancient house management measures in shop-house enterprises. It will lead to identifying potential EMMs that can be applied to all stakeholders including shop-house entrepreneurs, residents, planners and district managers

3. Methodology

The research objective is to compare the thermal comfort in modern and heritage building (Tomb of Mohammad Ghaus) in Gwalior, India and to present the techniques that can be adopted from ancient building for creating better thermal comfort in modern buildings with less energy consumption. For case study, building is selected from a range of naturally cooled heritage buildings considering various factors such as shape, size, design plan, types of ventilation and the physical state of the building like construction and material property. The climate characteristics like temperature (WBT and DBT), and relative humidity is calculated in one heritage building (Tomb of Mohammad Ghaus) and one modern style building of sub-tropical region from morning 8:00 am to 5:00 pm evening for a time of two days in month of April.

The inside temperature and humidity inside the heritage building was compared with the inside temperature and humidity of modern style building. The difference between the two is shown by graphs plotted. The measured data is compared with ASHARE standards to evaluate the thermal comfort in ancient building. It is hope that research will not only increase the energy savings but also helps in achieving maximum sociocultural advantages.

3.1 Description of Selected Heritage Buildings (Tomb of Mohammad Ghaus)

The case-study is conducted out in a one of the heritage buildings (Tomb of Mohammad Ghaus) positioned in the region of Madhya Pradesh that is 500 years old (shown in Figure 1). This building was constructed on rectangular plot typically facing the East side. The building of a 16th century prince-turned-sufi is now situated in the town of Hazira, Madhya Pradesh, India. The beautiful tombstone and the stunning architecture of the mausoleum give this place a sense of serenity and peace. The building's walls are inlaid with exquisite pierced-stone jail screen.

To the East of the town stands the mausoleum of Mohammad Ghaus. It is built in the form of square with Hexagonal Towers at its corners surmounted by small dome. The body of Heritage Building is enclosed on all sides by carved stone lattices of elaborate and dedicated design the whole being crowned by a big dome which was once inlaid with blue glazed tiles. The angle of Latitude and Longitude of Buildings are 78.1774527°N and 26.2317800° E respectively.

It was constructed during the reign of Mughal Emperor Akbar in 16th century. A true example of Mughal architecture, the structure holds great importance in the history of the country. The wall of the Tomb of the building has been carved using pierced stone technique and a number of chattris in blue tiles covers the tomb. Figure 2 and Figure 3 shows the inside view and some other features of selected heritage building. The intricate carving and the latticework are also something to watch for in the edifice. Set in a lovely garden and backed by a cemetery of the saint's devotees, the tomb is also the site of annual Tansen Music Festival.

Figure 1 Selected Heritage building for case- study (Tomb of Mohammad Ghaus)

Figure 2 Inside View of Heritage buildings with large ventilations

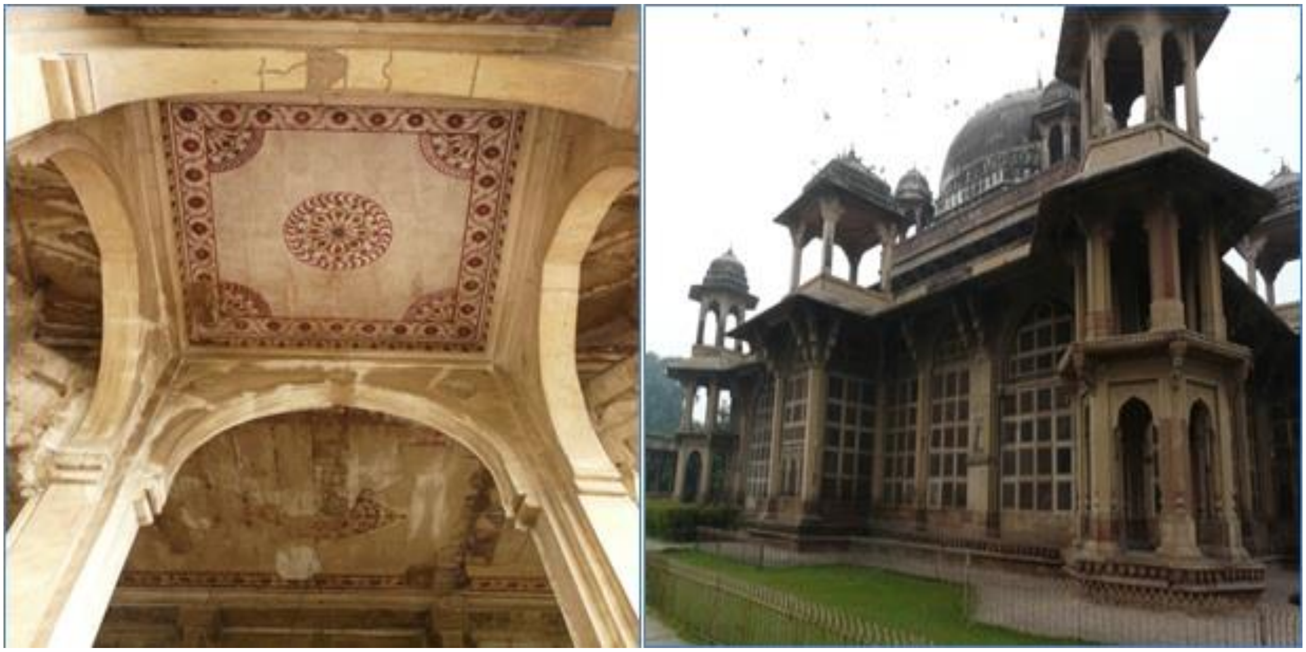

Figure 3 Salient Features of Heritage Buildings

4. Description of Selected Modern Style Building

The selected modern style building is approximately 10 years old and is located at a distance of 150m from heritage building in the same region of Madhya Pradesh. The Building is double story (ground and first floor) and has three bedrooms with other activity spaces such as veranda, study room, kitchen as shown in Figure 4. The modern style composed of bricks walls with plaster and reinforced cement concrete roof slab with use of iron rods without providing any types of insulation. Single glazed windows are provided. The width of brick walls is 10 inch that is covered with cement mortar. The maximum room height of the building is 3.5 m.

Figure 4 Selected Modern Style building for case- study

5. Thermal Comfort Index

According to ASHRAE Standards 55-2004, Thermal comfort is defined as "the situation of the mind that feels satisfaction with the thermal environment". The environment affecting the heat gained and lost by the human is termed as thermal environment. In order to evaluate the thermal comfort of any building, thermal comfort index is used. Some other indices are also available for evaluating thermal comfort like Predicted Mean Vote (PMV) method is used in air-conditioned structures; Adaptive neutral temperature model (ANTM) is used in buildings with natural ventilations etc. Therefore, ANTM is used in the study. Neutral temperature is the operative temperature at which the maximum number of people in a group feel neutral (neither cool nor warm). It is given by Eq. 1 (Fergus and Michael, 2010) as shown below,

$$T_n = 0.33T_{rm} + 18.8 \quad (1)$$

Some of the previous study on thermal comfort parameters (Temperature and Humidity) is shown by Table 3. As per the ASHRAE Standards, the thermal comfort temperature is upto 30 °C. In the study, the neutral temperature calculated using ANTM model for heritage and modern building are 27.69°C and 29.57°C respectively. Thus, in the heritage building better thermal comfort was noticed than modern structure. The maximum, minimum and average values of thermal comfort parameters are shown in Table 4 below for both modern and heritage building.

Table 3 Previous Studies on thermal comfort

S. No.	Author	Thermal Comfort Temperature Range (°C)	Relative Humidity (%)
1.	Vernon	18.94 in summer 16.72 in winter	35 to 70
2.	Bedford	18.16 in winter 13.22 - 23.16 comfort zone	30 to 68
3.	Markham	15.55 – 24.44 in ideal range	40 to 70
4.	Brooks	20.55 – 26.66 comfort zone	30 to 70
5.	ASHRAE Standards (55-2004)	24 – 30 comfort zone	

Table 4 Comparison of recorded thermal comfort parameters of modern and heritage building

	Outside Data		Inside Data Of Modern Building		Inside Data Of Heritage Building	
	Temperature (°C)	Rh (%)	Temperature (°C)	Rh (%)	Temperature (°C)	Rh (%)
Minimum	24	50	28	49	22.5	60.5
Maximum	40.2	85	37	78	33.1	73
Average	29.96	71.60	32.65	61.73	26.96	68.98
Neutral Temperature (T_n)			29.57 °C		27.69 °C	

5.1 Location of Sensors in Heritage and Modern Style Building

A number of sensors such as thermocouple, thermometer and hygrometer were fixed in traditional as well as in modern building for detecting ambient temperature and RH values outside the building as well as inside the building. The data measurements were carried out in both buildings during the same period (April 2018) of the hot summer season.

5.2 Uncertainty Analysis

Uncertainty is the key factor for determining the accuracy of the measured data. Uncertainty in the data is of two types, type A is due to random error and type B due to systematic error. The data is uniformly distributed, so here the type B uncertainty is calculated. The standard uncertainty of the instruments used for measurement is given by Eq. 2. The accuracy and standard uncertainty of the instruments used is shown by table 5.

$$\text{Standard Uncertainty} = \frac{\text{Accuracy of instrument}}{\sqrt{3}} \quad (2)$$

Table 5 The technical specification of the instruments used in the experiments

Instruments Used	Accuracy	Range	Standard Uncertainty
Thermocouples	±0.1°C	-20 to 400 °C	0.288
Digital hygrometer (model HT-315)	0.1 % RH	10 % to 95 % R.H.	0.068
Pyranometer (version WACO-206, least clarity ± 10 W/m2)	± 10 W/m^2	0-24 hours	0.00058

6. Result and Discussion

The data measurement had been conducted in summer season of Gwalior, Madhya Pradesh i.e. on 16th of April 2019 for duration of 24 hours. From the obtained data it was found that in ancient buildings ambient outside temperature has a temperature swing of 17.3°C, i.e. from 24°C to 41.3°C, while inside building temperature was altering from 23.2°C to 29.0°C showing everyday swing of the about 5.8 °C only (Figure 5). Inside ambient temperature at the time of night is maintained at around 23.2°C and outside ambient temperature at the same time is around 25.8°C. The relative humidity inside fluctuates from 56% to 100%. Then compared with ASHRAE standards it was come to know that inside temperature falls in the thermal comfort zone. This is because the ancient building has Maximum walls thickness, large area veranda,curved terracotta roof tiles, yards, and wind catchers above the yards for natural ventilation for cooling purpose.

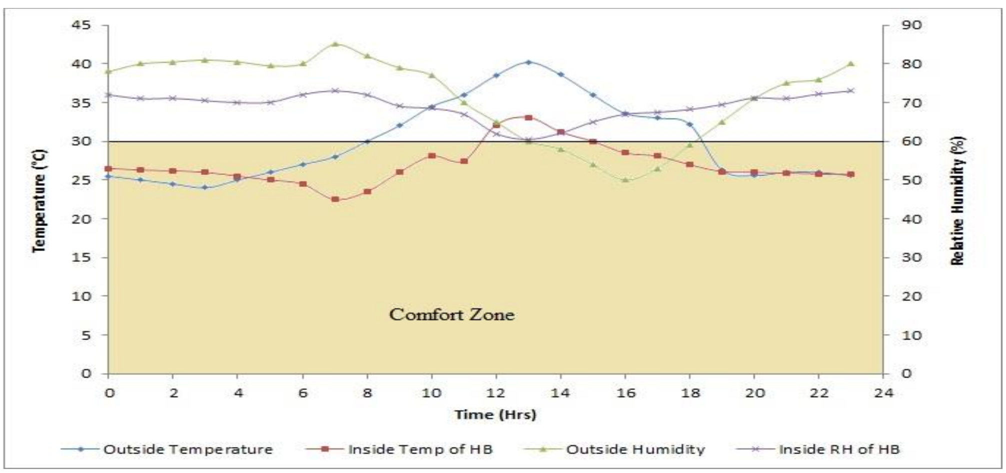

Figure 5 Comparison of inside temperature and relative humidity with ambient temperature and relative humidity for Heritage building

In modern style buildings the ambient temperature swing of 16.2°C was found while the inside house temperature varies from 28°C to 37°C showing the diurnal deviation of 9°C (Figure 6). From the data it is clear that the maximum temperature inside the room was around 37°C and the minimum temperature was about 28°C. When these data matched with ASHRAE standards it was found that inside room temperature does not fall in the comfort zone. The reasons behind this are that the modern style buildings has Concrete roof with iron rod, small sunshades, minimum thickness of wall, and small ventilation for cooling. Figure 7 shows that inside temperature variation in the ancient building and modern style buildings. It is noted that minimum temperature in the ancient buildings is 22.5℃ and the minimum temperature noted in the modern style building is 28℃.

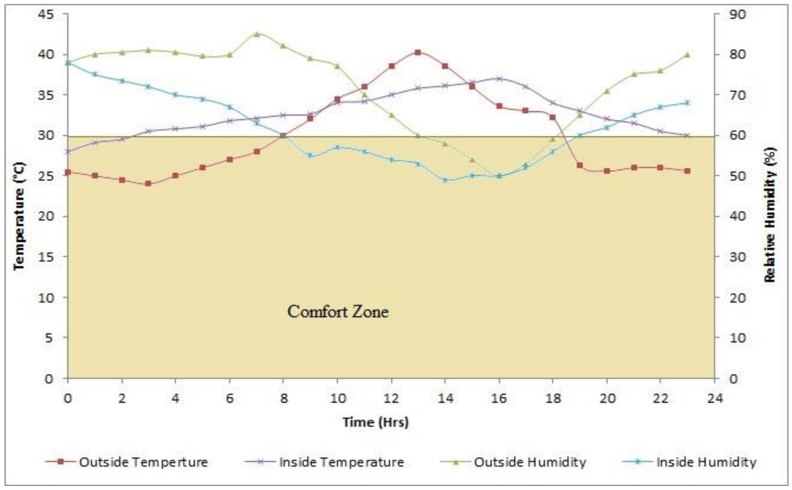

Figure 6 Comparison of inside temperature and relative humidity with ambient temperature and relative humidity for Modern style building

From Figure7 it is clear that minimum temperature is greater by 5.5°C in modern style buildings when compared with minimum temperature of the ancient buildings. The maximum temperature in modern style buildings is higher than traditional building by 5.5°C.

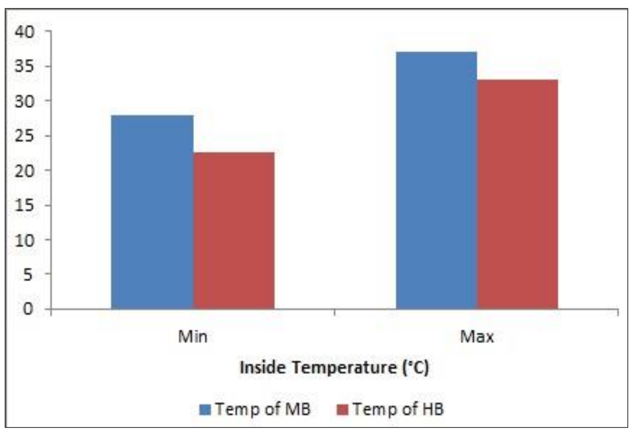

Figure 7 Inside temperature variation in Heritage and Modern style Building

The ambient temperature is varying from 24°C to 40.2°C. As from Figure 8 it is clear that the temperature inside the heritage building was close to the thermal comfort temperature range given by ASHRAE. While in modern building, the inside temperature is crossing the limit of thermal comfort for more time as compared to heritage building. The maximum temperature inside the heritage builging was 33.1°C while in modern building it was 37°.

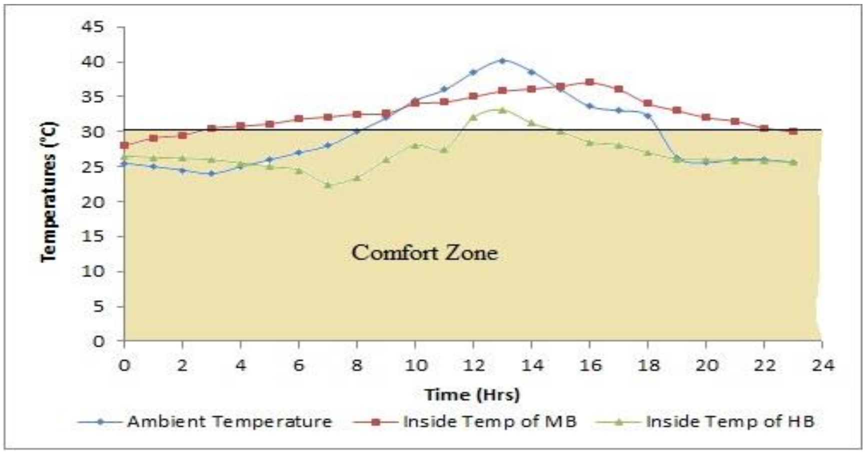

Figure 8 Variation in Inside temperature in comparison to ambient with Time for heritage and modern style building

7. Conclusion

It is observed that the Ancient building is more thermally comfortable than the Modern style building for the same environment. The inside ambient temperature is tremendously much greater in modern style building then the Ancient building with the same outside temperature in both the buildings. The causes for significant temperature difference between inside and outside temperatures of ancient building in summer is because of that the evaporative cooling phenomena take place in mud mortar based traditional houses. Low thermal conductivity and less thickness of roof and walls of concrete based modern style buildings shows the higher temperature differences when compared with traditional buildings. As a result, it can be concluded that the solar natural features used in traditional buildings should be used in the modern style.

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