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Thermal Performance of Naturally Ventilated Traditional and Contemporary Houses: A Case Study of Mandla, M.P., India

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ABSTRACT
Traditional buildings are those built by people to satisfy their everyday needs, generally using locally obtained materials and expensive methods. The result of traditional knowledge obtained through trial and error is the construction of traditional buildings. Transformations in settlements, whether urban, rural, or tribal, are inescapable, and this can be seen in the investigated region as well in the shape of freshly erected modern structures. The goal of this study is to compare the thermal efficiency of traditional Gond dwellings with contemporary buildings in Mandla, Madhya Pradesh, India. This study selects three dwellings that reflect the three principal typologies observed in the location of choice. The purpose of this article is to illustrate the impact of building skin on dwelling thermal performance. The goals of this article are to find and select the most typical houses in the neighborhood, as well as to assess their thermal efficiency. The technique comprised a study of the literature, documentation, and measurements of air temperature, air velocity, relative humidity, and case analysis. The thermal efficiency of the three types of houses is investigated and monitored during peak winter and summer days of the year. Certain suggestions are provided in order to increase the thermal performance of the dwellings.

Keywords: Thermal Performance, Simulations, Tribal houses, Gond tribes.

Introduction

The building skin is the principal subsystem in construction that influences and regulates prevailing exterior circumstances to suit the comfort requirements of the user within the structure. This, like human skin and clothes, performs the responsibilities assigned to it by fulfilling a variety of functions made feasible by adequate design and structure (Schittich, 2012). Building skins are directly exposed to the elements. Indoor comfort varies according to the skin of the structure. A good skin helps to increase interior thermal comfort while also lowering energy use. As a result, the skin of a structure plays an essential part in enhancing the thermal conditions of the dwelling as well as providing better thermal conditions for the occupants.

The main sources of traditional architecture include the local population, local resources, local culture, as well as regional techniques that have been handed along over the years. It is impacted by a wide range of diverse characteristics of human behavior and the environment, resulting in a variety of built forms for practically any possible setting. Climate-responsive buildings are now necessary to meet this increasing demand for energy. Regardless of changing cultural, economic, construction technology, and energetic conditions, the primary aim of architecture is the creation of a pleasant "shelter." In other words, the primary goal of construction is to shield humans from the effects of external climatic variables such as intense sun radiation, harsh temperatures, precipitation, and wind. Traditional shelter can be tied to the dominant cultures of the population and serve as emblems of identity while also reflecting the environmental specifications of that location (Shaheen, 1975).

Contemporary shelter is usually viewed as an illustration of internationalism, which eradicates local customs and converts the world into a faceless urban sprawl (Huppauf & Umbach, 2005).

For thousands of years, tribal peoples have developed rich and colourful vernacular architecture styles that adapt to local environments. This is the result of an evolutionary adaptation to geography, nature, ethnic distribution, and sustainable ecosystems (Wang, 2006). As per the 2011 census, there are 109 million Tribes in India, which accounts for 8.6% of the country's total population. The article 342 of the Indian Constitution has a schedule (list) of the Tribal communities that are economically and socially disadvantaged. Most tribes in Central India (Gondwana) are composed of Gonds. The population of this tribe makes up 13.45% of all scheduled tribes in India. In terms of the overall number of scheduled tribes in the state, Madhya Pradesh has the highest proportion of Gonds (43.69%). Maharashtra (19.47%), Odisha (9.97%), Karnataka (6.47%), Andhra Pradesh (5.04%), and Bihar (1.57%) are the next states with the highest percentages of Gonds.

India is a large nation with a climate ranging in terms of geographical and topographical conditions, from the sparking sun to frost blowing cold. As a result, there is a need to formulate and implement specific design criteria for specific locations based on their geo-climatic conditions. India is divided into five climatic zones according to the National Building Code (2016) namely: Hot & Dry climate, Warm & Humid climate, Cold Climate, Composite climate and Temperate Climate. Especially in Composite climates which almost covers $1/3^{rd}$ of the nation. Furthermore, traditional dwellings are becoming extinct, and knowledge of their construction procedures is disappearing. As a result, there is an obvious need to preserve information regarding vernacular construction practices.

According to the 2011 census, scheduled tribes make up 8.6% of India's overall population. The largest scheduled tribal population in India is found in Madhya Pradesh. And over 1.6 crore Schedule Tribe people live there, making over 21% of the state's population. 3,122,061 tribal households, or around 15% of all tribal dwellings in the nation, are located in Madhya Pradesh. There are 894,236 people living in the Mandla district overall, among whom 5,11,798 (57.23%) are scheduled tribal members (Census, 2011). Furthermore, traditional dwellings are becoming extinct, and knowledge of their construction procedures is disappearing. As a result, there is an obvious need to preserve information regarding the traditional construction practices.

This study seeks to increase knowledge of the concept in relation to both traditional and modern buildings in Mandla's composite climate. The objectives of the study are to identify and select the most representative houses in the studied area and examine the thermal performance of the same.

Theoretical Framework

Thermal Comfort

It is commonly defined as the desired or pleasant state of mind that a person feels in response to how whether it's warm or frigid they are. As a result, it is closely tied to the person's surroundings. Notwithstanding being called that, it impacts merely comfort, yet efficiency, wellness, and health, therefore contentment with the thermal environment is critical (Chow, 2022).

It is described as the state of mind that expresses satisfaction with the thermal environment and is assessed subjectively (ASHRAE, 2020). Another way to define thermal comfort is the ability to remain neutral in the face of a specific thermal environment while being aware of it and not perspire. In tropical places where temperature and humidity tensions are still significant, human thermal discomfort is a major issue. A person's location and the weather both within and outside the enclosure affect the thermal comfort requirements (Balbis-Morejón et al., 2020).

Thermal Performance of buildings

It relates to the procedure of modeling the transmission of energy between the building and its surrounding environment. It calculates the heating and cooling load for conditioned buildings, allowing required size of HVAC (heating, ventilation, and air conditioning) equipment. Naturally ventilated houses are taken into account in this study. It estimates the variation inside the building during a specific time period and assists in estimating the duration of discomfort hours, for these houses. Many different aspects affect a building's thermal performance. It is possible to summarize them as follows: (i) design variables, which include the geometric dimensions of building elements like walls, roofs, and windows, as well as their orientation and shading devices; (ii) building material thermal properties, which include density, specific heat, thermal conductivity, and transmissivity; (iii) weather data, which includes solar radiation, ambient temperature, wind speed, humidity, and other meteorological information; and (iv) usage data, which include internal gains from occupants, lighting and equipment, air exchanges, etc. With the right analytical tools, the impact of these aspects on a building's performance may be investigated. There are several methods for assessing a building's performance. They fall into one of three categories: correlation, dynamic, or steady state approaches (Nayak et al., 2006). Random cooling and heating effects during construction, particularly at the facades and roofs, affect low-rise structures' thermal efficiency. (Vijayan et al., 2021).

Brief Literature Review

Many studies on the thermal comfort of individual dwellings, apartments, and other types of vernacular buildings have been carried out in India (Sharma et al., 2021). When compared to modern homes, Dili et al. (2010)'s evaluation of thermal comfort in Keralan traditional structures revealed that passive approaches were effective in raising internal temperature, humidity, and air velocities. In three different cities in north-eastern India, Singh et al. (2010) conducted an investigation into the comfort conditions in free-running vernacular buildings. They found that because traditional buildings have more advanced controls and adaptation mechanisms, occupant comfort is possible in a wide range of temperatures. Additionally, three distinct comfort models were developed by Singh et al. (2011) that were especially appropriate for each of the three climatic zones. Indraganti (2010) conducted a study on the coping mechanisms and comfort levels in Hyderabad's free-standing flats. Indrganati and Rao (2010) further showed that the comfort ranges are greater than those given by international standards since adaptive measures were included. They also determined how income, age, gender, and building characteristics affected thermal comfort. Rajasekar & Ramachandraiah (2010) conducted their fieldwork in apartments within Chennai's hot, humid atmosphere in contrast to Indraganti's study in a composite climate, and their findings showed a lower comfort range. Thapa (2020) estimated the comfort temperature ranges within high-altitude residences located in colder regions of Darjeeling which were outside the suggested ranges by ASHRAE Standard-55. The comfort temperature varies depending on the occupants' gender, age, and body composition, as per Thapa's study. A recent national initiative to create a thermal comfort model for Indian homes situated in various climate zones was also completed (Rawal et al., 2022). The amount of affordable housing and the method for including several climatic zones into a single model are both limited, despite the fact that the field data collected as part of this work is representative of various climate zones and residential construction typologies. Despite improvements in Indian thermal comfort research, the scientific literature still lacks field investigations that concentrate on various vernacular style across the India.

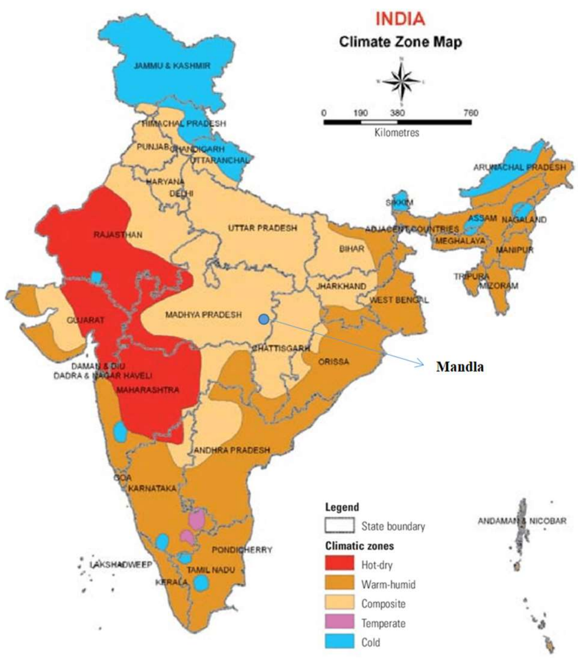
Singh et al (2010) assessed the thermal performance of vernacular dwellings in Northeast India. It was shown that, with windows, doors, and ventilators covering 50% of the total surface area, the window-to-wall ratio remained 0.216, and that, with the right insulation, heat transfer lagged by 5–6 hours and internal temperature fluctuations did not exceed 10 C. In three different N-E climatic zones over the course of four seasons, Singh et al. (2009) performed comfort questionnaires and recorded the responses of many residents. Based on the actual and predicted mean votes, they found that the residents adapt to various degrees in different seasons and climates. Additionally, Singh et al. (2009) optimized the design of vernacular buildings in Northeastern India using TRNSYS 17. Three building types and eight different 3D model orientations were used to optimize the design. As a result, it was proposed that a ventilator be used, as well as windows with big apertures, double-glazed windows, and suitable shade. The impact of supplying courtyards in traditional vernacular structures was researched, and it was discovered that using a courtyard gives a cooling effect within the home during the afternoon Myneni, 2013). The thermal efficiency of new and historic heritage-type structures—such as vernacular homes—was compared by Kushwah et al. (2020). They found that the thermal performance of traditional homes with solar passive features is superior to that of concrete homes. Adding passive features to vernacular homes not only increases their energy efficiency but also reduces pollution to the environment. Using analytical and experimental methods, (Chávez et al., 2016) evaluated the effectiveness of the Hydrodynamics Cool Roofs System with Energy Recovery, an environment conditioning system (SHETRE). They found that SHETRE raised the comfort hour by 68% and lowered the inside temperature by 8 degrees Celsius when the outside temperature hit 35 degrees Celsius. Aflaki et al. (2015) claim that because of the dominance of cloud cover, high humidity, and a lack of temperature fluctuations, radiative cooling is ineffective in tropical climate zones. Cabeza & Chàfer (2020) examined and categorized technologies that may be applied to "zero energy" buildings. They suggested a variety of strategies, such as the utilization of energy storage devices and non-conventional energy sources, to fulfill the energy demand. In their examination of the many uses of phase-changing material (PCM), Irfan Lone & Jilte (2021), Tiji et al. (2020), and Hu et al. (2020) found that PCM construction is space-efficient, compact, and can replace typical thick-mud structures or heavy constructions. PCM can be positioned on the ceiling, walls, or roof, or it can be sandwiched between layers to take use of its capacity to hold latent heat. According to these PCM studies, passive features can lower outside air temperature by up to 30 degrees Celsius, which can help reduce ASHRAE-recommended cooling load requirements and building-related CO2 emissions. However, they cannot significantly lower outside air temperature from a very high level (say, 45 degrees Celsius) to a neutral interior room temperature level (say, 20 degrees Celsius).

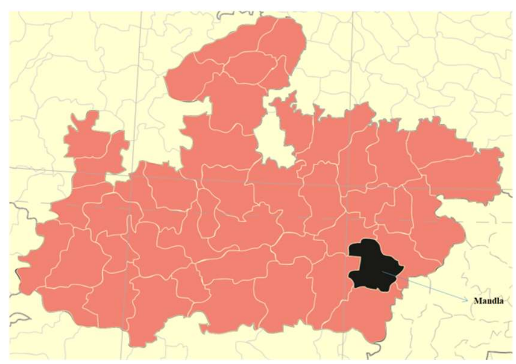
Methodology

Studied Area

Madhya Pradesh is located in the central part of India. As indicated by the two colours in Fig.1. it may be divided into two types of climatic divisions: composite zone and hot-dry climate.

To study the role of building skin on thermal performance of gond houses Mandla is choosen as it constitute the maximum number of Gond tribes in the composite climate of Madhya Pradesh. In this study three villages namely Bichuwa, Salaiya and Umaria are choosen for the further investigation which are 13 kms, 22 kms and 32 kms respectively from Mandla. The population distribution for the villages in Mandla was examined using census data from 2011, and it was discovered that 41% of these villages are within the population range of 500-999, which is the highest percentage. During the pilot survey of these villages two types of houses are identified in the villages which are traditional houses and contemporary houses.





Location of Mandla district on Madhya Pradesh

Fig.1: Climatic zone classification as per National Building Code 2016 and Madhya Pradesh and Mandla location in the classification

Source: National Building Code, 2016

Three different typologies were observed. As in Traditional houses there are two types; one is Mud wall another one is brick wall with mud mortar. Third one in Contemporary house is brick wall with cement mortar. Roofs in Traditional house are made up of burnt clay roof tiles while Contemporary houses are having RCC slab. The thickness of mud walls varies from 350 mm to 450 mm while of Brick wall with mud mortar are 230 mm-300 mm. Contemporary houses having brick walls with cement mortar is 230 mm (external wall) and flat reinforced cement concrete (R.C.C.) roof 100-115 cms were found.

Climate

Mandla falls under composite climate as shown in Fig.1. As per climate data from 1981-2022 it can observed that May is the month of peak summer and month of December is the month of peak winter as shown in fig. 2.

PEAK SUMMER MONTH (May) — PEAK WINTER MONTH (December)

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C (°F)	18.5 °C (65.3) °F	22.1 °C (71.8) °F	26.7 °C (80) °F	31.5 °C (88.7) °F	33.9 °C (93) °F	30.1 °C (86.3) °F	25.6 °C (78) °F	25 °C (77) °F	25.4 °C (77.7) °F	24.6 °C (76.3) °F	21.8 °C (71.3) °F	18.9 °C (66) °F
Min. Temperature °C (°F)	11.3 °C (52.3) °F	14.6 °C (58.3) °F	18.8 °C (65.8) °F	23.4 °C (74.1) °F	26.9 °C (80.4) °F	26 °C (78.8) °F	23.4 °C (74.2) °F	22.9 °C (73.2) °F	22.3 °C (72.2) °F	19.3 °C (66.8) °F	15.3 °C (59.5) °F	11.8 °C (53.3) °F
Max. Temperature °C (°F)	25.8 °C (78.4) °F	29.4 °C (84.9) °F	34 °C (93.3) °F	38.7 °C (101.7) °F	40.3 °C (104.6) °F	34.9 °C (94.8) °F	28.6 °C (83.4) °F	28 °C (82.4) °F	29.2 °C (84.6) °F	30.1 °C (86.2) °F	28.5 °C (83.4) °F	26.1 °C (79) °F
Precipitation / Rainfall mm (in)	13 (0)	17 (0)	17 (0)	8 (0)	9 (0)	200 (7)	465 (18)	396 (15)	210 (8)	39 (1)	9 (0)	9 (0)
Humidity(%)	48%	41%	30%	23%	26%	54%	84%	87%	81%	62%	52%	50%
Rainy days (d)	2	2	2	2	2	11	19	19	13	4	1	1

Fig. 2: Average of 1981-2022 climate data for Mandla, M.P. shown in tabular form
Source: meteoblue.com

Research methodology

Selection of villages and identification of sample houses were done on the basis of prominent population of gond tribes in the villages. The most representative houses of the villages were selected for the detailed study. Criteria for selecting it was to firstly select the most representation village of the population which is shown in section 3.1. Then for house certain characteristics were listed down. For traditional house (i). House should be naturally ventilated (ii). House should fall under the observed typologies (iii). House should be built with traditional materials (mud walls, brick wall with mud mortar, clay tiles on roof, mud flooring). For contemporary house (i). House should be naturally ventilated (ii). House should fall under the observed typologies (iii). House should be built with contemporary materials (brick wall with cement mortar, flat R.C.C. roof, cement flooring). Detailed Air temperature, Relative humidity and wind velocity were measured for 3 days period in each selected house with the help of data loggers during the peak winter season and summer season. Peak winter season and summer seasons were identified by analysing the last 41 years available weather data of Mandla, M.P. Simulations were done in design builder software. After creating models of selected three dwellings simulations were run for whole year to get the number of discomfort hours due to unwanted cold and heat as per ASHRAE 2020. Verification of simulations result with the actual measurement was done. Identification of the dwellings showing better thermal performance among the three dwellings has been done and further suggestive measures for improving thermal performance in Mandla's composite climate are given.

Instrument Used

Table. 1: Details of Instrument used during the study
Source: Author

INSTRUMENT NAME	COMPANY	RANGE	ACCURACY
Onset HOBO MX 2301A	HOBO	0 to 100% RH, & 40° to 70°C	+/- 0.2C° and +/- 2.5% RH
TESTO 435 with probe	TESTO	-50 to +150 °C	±0.2 °C, 0 to +100 %RH 0 to +60 m/s

Fig.3: Onset Hobo MX 1101 (on left) & Testo 435 with probe (on right)
Source: Author

Table 1 shows the range and accuracy of the used instruments. Data logger Onset Hobo MX 1101 shown in Fig.3a. was used to get the 3 days long Air Temperature, Relative Humidity and wind velocity data. Hand held Instrument Testo 435 shown in Fig.3b was also used for getting the inside and outside Air Temperature, Relative Humidity and wind velocity data at intervals. The results of the simulation for the various dwellings' thermal discomfort levels are validated by actual temperature readings using the root-mean-square error (RMSE) or root-mean-square deviation (RMSD). It is a widely used metric for calculating the differences between values that an estimator or model predicts and actual values (population and sample values) (Kambezidis, 2012). By comparing the actual difference between the estimated and measured values, term by term, the RMSE statistic provides insight into the short-term performance of a model (Ma & Iqbal, 1984). The model performs better when the value is smaller (Stone, 1993).

Description of the Case Study

For the study, as per the percentages of types of houses presented in the villages sample houses were selected for each category.

Traditional House with Mud wall

View from west

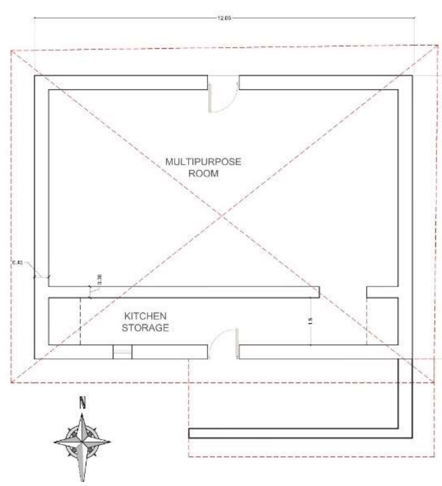


Fig. 4. Side view and Ground floor Plan of Traditional House with Mud wall
Source: Author

The house selected is having age of around 60 years and was built by own family shown in Fig 4. It has built up are of 108 sq.m. It has one multipurpose room which is used for sitting and sleeping purposes while they have kitchen and storage just after the entry to their house. This house has Mud walls of thickness 450 mm for external wall and 350 mm for internal walls. Height of the outer walls is 2400 mm and of internal walls is 2800 mm. Total height at the centre of the house is 5200 mm.

Traditional House with brick wall and mud mortar

View from South

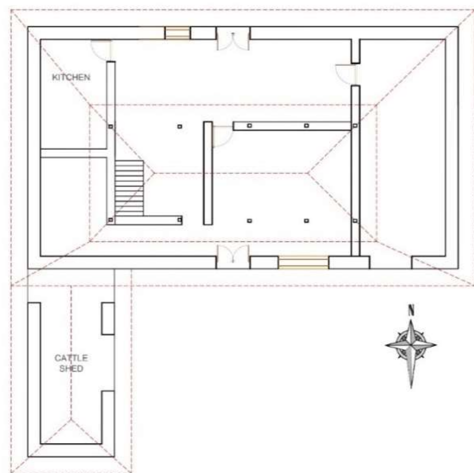


Fig. 5: Front view and Ground floor plan of Traditional House with brick wall & mud mortar

Source: Author

The house selected is having age of around 35 years and was built by own family and with the help of some labours shown in Fig 5. It has built up are of 132 sq.m. and a separate cattle shed is provided of area 20 sq.m. Cattle shed is not taken into consideration as it is not a habitable space. It has four multipurpose rooms and one kitchen at the back. This house is made up of brick walls with mud mortar of thickness 300 mm for external wall and 230-250 mm for internal walls. Height of the outer walls is 3100 mm and of internal walls is 3500 mm. Total height at the centre of the house is 5200 mm.

Contemporary house

View from North

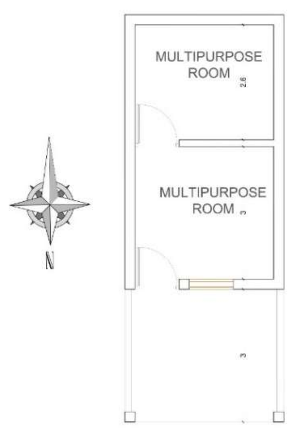


Fig.6: Front view and Ground floor plan of Contemporary House

Source: Author

The house selected is made a year ago shown in Fig 6. It has built up are of 33 sq.m. It has two rooms. Wall are made up of bricks and cement mortar and of thickness 230 mm. Total height of the house is 3000 mm.

Location of temperature sensors

The temperature was measured and hourly data was collected using data loggers so that daily variations inside each house could be analyzed. As seen in fig. 7, the data loggers were positioned in the middle of the space, between 1000 and 1200 mm in height. Based on the typical human height when seated, 1.0 m was calculated (Das, 2006). Data loggers were put in every room in the center and programmed to capture data continuously for three days, 24 hours a day. A one-day average of the three-day data was then calculated. At intervals of one hour, all data were automatically collected (60 minutes). Further the hourly data obtained for each space was averaged to single house data and was compared to the average outdoor temperature during the week of measurement.

Fig 7: Location of sensors in the selected houses
Source : Author

Analysis of result

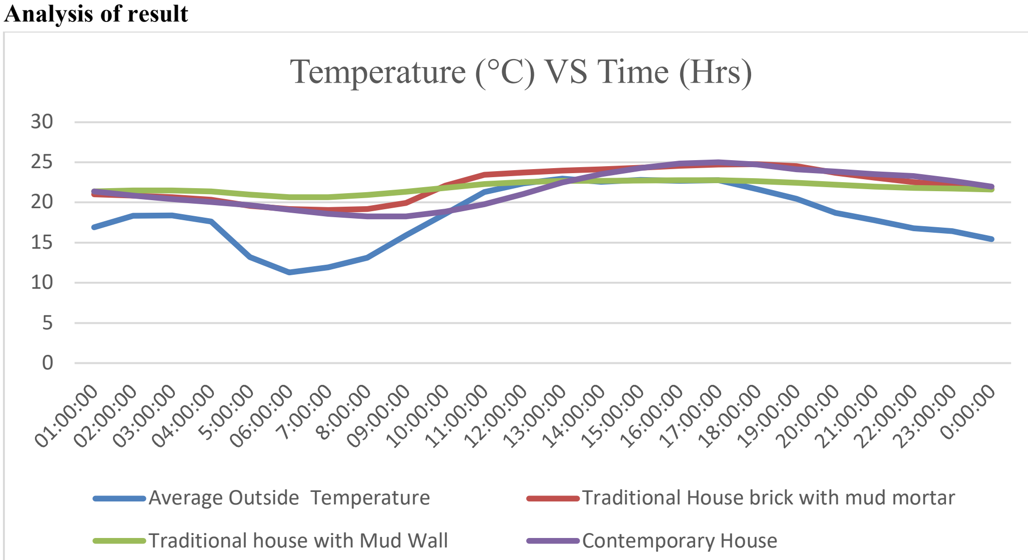


Fig.8: Outside and Inside Temperature variation over 24-hour cycle in peak of winter
Source : Author

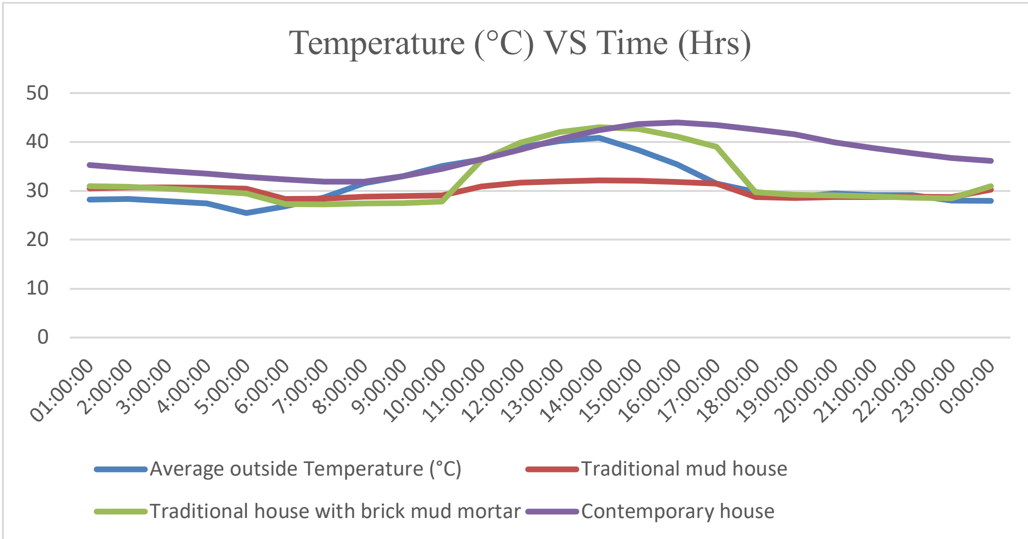


Fig 9: Outside and Inside Temperature variation over 24-hour cycle in peak of summer. Source: Author

Peak winter recorded average temperature in week from 11th December 2022 to 17th December 2022

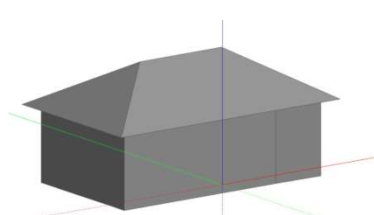
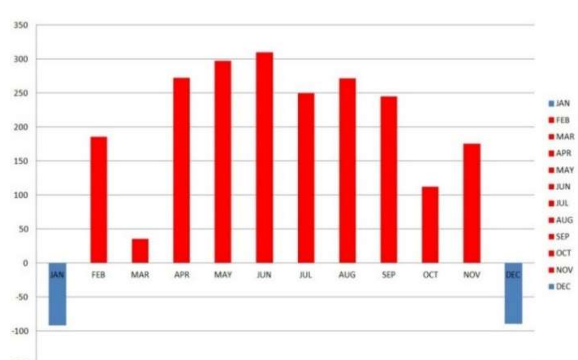
The graph (Fig. 8) above displays the average temperatures that were observed throughout a week during the coldest part of the year, which runs from December 11 to December 17. The recorded temperatures of the three sample houses are displayed on the three distinct colored graphs. The fluctuation in the average outdoor temperature during the same time period is depicted in the blue graph. With temperatures recorded up to 4-5 degrees Celsius higher than other samples, the traditional brick and mortar home performs better in the winter than the contemporary home and the traditional house with mud walls.

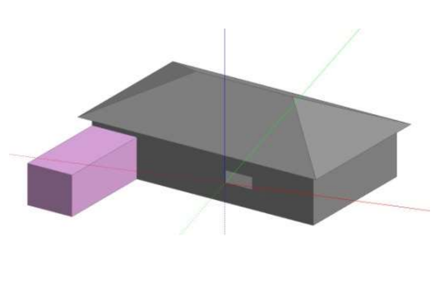
Peak summer recorded average temperature in week from 20th May 2023 to 27th May 2023

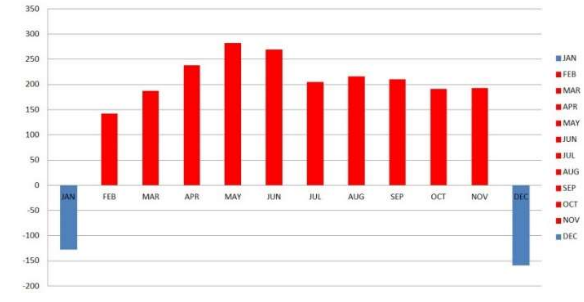
The graph (Fig. 9) above depicts the average recorded temperature over a week during the warmest part of the year, from May 20 to May 27, 2023. The three colored graphs represent the average recorded temperatures of the three sample huts; the blue graph represents the deviation of the outside average temperature during the same period; and the mud house represents the constant temperature range.

Table 3 : Showing the discomfort hours

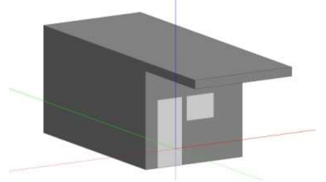
Source : Author

Type of Dwelling Unit	**Discomfort Hours**
Traditional House with Mud wall 	Traditional House with Mud wall 
Traditional House with brick wall and mud mortar	Traditional House with brick wall and mud mortar

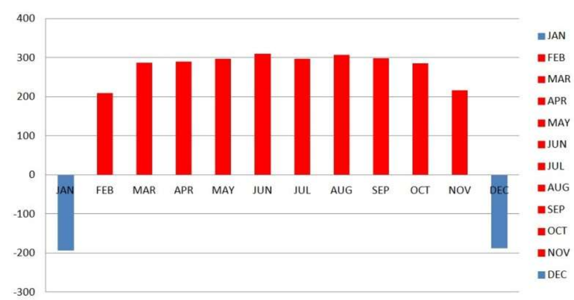




Contemporary house



Contemporary house



Data for simulations

For building design and manual load calculations, for instance, generic climatic data is provided by ASHRAE/ISHRAE design handbooks and guidelines. Studying the performance of buildings year-round will require annual meteorological data. It has become clear from the development of intricate computerized simulation programs for building thermal response that a consistent collection of data is required to represent hourly annual data. The majority of data systems use periods from real data that has been gathered over several years to build a composite year's worth of data. This data is referred to by several names, including EPW in India and the US. In this instance, simulations are produced using the design builder. Latest Mandla's EPW file, which includes air temperature, air velocity and humidity data were used. Summertime discomfort is more prevalent in the months of April, May, and June, with wintertime discomfort being significant in January and December.

Discussion

It was observed during case study that the Traditional house with mud walls has the better thermal performance during the winter period. Data was compiled with computer simulations, in which ASHRAE 2020 was used for calculating the discomfort hours throughout the year. The U-value of the mud was found to be 1.3 Watt/sq.m Kelvin. It is noted that high thermal capacity of mud walls of thickness 350 mm (internal walls) and 450 mm (external walls) plays an important role in maintaining the optimum temperature even during the night time decreased outside temperature. When the sun sets and the heat source is removed in the evening, since additional heat is needed in the interior environment, materials with high thermal mass store solar energy that has made it into the space through openings and remained trapped during the winter. This heat is then gradually returned to the interior. As a result, the building's heating burden is reduced (Gregory, 2008).

Table 3 shows the comparison of three selected houses. The total number of discomfort hours caused by excessive heat is greatest in the Contemporary house, i.e. the house of brick with cement mortar and RCC slab, followed by the Traditional house of brick with mud mortar, and the Traditional house of mud walls has the least discomfort due to excessive heat. It can be studied from the analysed data that the Traditional house with the mud walls is having lesser number of discomfort hours throughout the year. It is having 2334 discomfort hours throughout the year. Even the inside temperature of the dwelling were maintained constant during 24 hour measurements. While the outside temperatures change significantly throughout the day, the temperatures recorded within the mud dwellings vary barely, keeping nearly constant throughout the day, resulting in an almost straight-line graph as shown in fig. 8. During the peak winter period the thermal behaviour of skin of house with the mud walls was favourable during the night time when the temperature outside decreased , the recorded temperatures within the dwelling remained higher than the other two types of dwellings due to the mud wall thermal lag properties. The excellent mud's thermal properties which allow for thermal time-lag within the mud dwelling, function effectively in winter by maintaining night-time temperatures higher than the chilly outside temperatures. The other dwellings, Traditional house brick with mud mortar and Contemporary house shows discomfort hours 2420 hours and 3175 hours respectively. The Traditional house with brick mortar performed better than the Contemporary house made from brick with cement mortar in terms of discomfort hours and outside-Inside Temperature variation over 24-hour cycle in peak of winter.

Conclusions

The purpose of this research was to examine the thermal performance of traditional and contemporary dwellings in Mandla, M.P., India during peak winter and peak summer to make recommendations for a thermally pleasant environment. This study was motivated by the need to develop alternate strategies of attenuating and mitigating the issues of climate change by drawing typological lessons from the similarities and contrasts in traditional as well as contemporary architecture in providing thermally acceptable surroundings. It was discovered from this study that traditional house performed better than contemporary house in terms of discomfort hours, That is, their exceptional thermal properties might be utilised to discover typological concepts. Traditional buildings adhere to sustainable design principles as well since they produce no waste, are connected to the environment, and pay attention to local characteristics. They used less energy and cost less money since they were constructed using locally accessible materials and climates, as opposed to relying on artificial and mechanical HVAC systems.

In light of this, the study suggests that rather than depending exclusively on active design strategies, architects and planners in regions with climates similar to Mandla should make a concentrated effort to incorporate passive design strategies into the provision of a comfortable indoor thermal environment through the use of traditional construction materials. The study's conclusions show that, in spite of their lack of design strategies, older buildings recorded lower air temperature readings than contemporary ones.

Certain recommendation are being made

1. Rather adding up the thermal mass as Traditional house with mud walls in Contemporary house, a layer of thermal insulations can be added to increase the thermal performance of the same so that the thickness of the walls can be reduced. It is feasible to use PCM construction.
2. Cool roofs and green roofs can use. Since cool roofs reflect sunlight, green roofs insulate using soil and plants. Both lower the amount of energy used by the building for cooling and/or heating.

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