Illustration by Shashank Manohar | 8th sem

12. Thermal Performance of Mud in Composite Climate: An Overview.

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Kalpa, Vol.04, 2023, pp. 75-80

Abstract :

Indoor thermal comfort can be increased through the careful selection of building materials, among other things. India has a wide range of weather extremes, from warm and humid to cold and dry. Across a sizable portion of the country, the composite climate predominates among several climatic conditions. Twenty-percent of the world resides in earthen dwellings, and many rural people have lived in mud huts for generations as an integral part of their culture. This research examines rural indigenous mud-based construction, the characteristics of mud and how well it performs thermally in the diverse climatic conditions of India. The fundamental thermal properties of mud have been researched to establish its suitability and successful use in the seasonal fluctuating traits of a composite climate. Ranchi, the capital city of Jharkhand has been taken into consideration as an example to demonstrate the performance in a typical composite climatic zone.

Keywords:

Building Construction Material, Composite Climate, Thermal Mass, Thermal Performance.

Introduction:

Gernot Minke (2005) suggests that clay block construction was a popular practice in dry, hot, subtropical and moderate climatic zones and it is still a convenient, affordable, straightforward, and environmentally beneficial building material for several native rural buildings. According to the 2011 Census (Census, 2011)[1], mud walls are still present in over half of all Indian houses. Over 1/3 of the population in the world, according to Dr. B B Puri (2003), lives in mud huts. The following traits, which are most prevalent in rural areas, have a major impact on the indigenous architecture of that area.

- Climatic Conditions
- Locally available building material
- Local construction techniques
- Social customs and traditions (Susilo, 2007)

From the above, it is clear that in areas where clayey soil/earth is available in abundance, mud is the most accessible, cost-effective, and practical building material for rural housing. This study investigates how mud performs as a building material in the diverse environment of rural India, focusing on its thermal characteristics. Many tribes in eastern, northeastern, and central India have mud huts as a part of their cultural history. For India's rural population, it is crucial to improve them by enabling improved thermal comfort indoors. As they are readily available, affordable, and relatively simple to work and construct with, mud and straw are the oldest construction materials in human history. Mud's plasticity and versatility has enabled its use in constructing various structures, from desert huts to multi-story homes, across diverse terrains. Using both ancient architecture and contemporary technologies, mud construction is necessary for a sustainable future society (Hassan, 1973)

According to Dr. B B Puri (2003), there are two general groups of mud buildings: those made using traditional methods and those made using modern methods. The majority of traditional rural homes are built using the following traditional techniques:

1. Sun-dried brick or adobe
2. Rammed earth buildings
3. Wattle and daub[2] building

The modern methods consist of:

1. Blocks of compacted mud
2. Blocks of stabilised, compacted mud
3. Stone facia and compacted mud blocks
4. Mud blocks with chemical stabilisation
5. Pneumatic ramming of the earth

Of all the techniques and methods mentioned above, rammed earth technique is effective in both conventional and modern approaches. Rammed earth building was first used in India in 1948 when 4000 homes were built in Karnal (Haryana). These homes have now been occupied for more than 50 years. With an extensive analysis through trial and error, vernacular architecture often expresses an ideal form, which is extremely responsive to the environment and the materials at hand (Cooper, 1998). With an extensive analysis through trial and error, vernacular architecture often expresses an ideal form, which is extremely responsive to the environment and the materials at hand (Cooper, 1998).

The ensuing paragraphs present some facts about the

[1] https://censusindia.gov.in/census.website/

[2] Wattle and daub : Mud mixed with the framework of Bamboo

thermal performance of mud walls, frequently used in the construction of rural mud-dwellings in Ranchi, Jharkhand, situated in the Indian subcontinent's composite climatic area.

Key Features of Composite Climate

There are 5 different climatic zones in India, as per NBC (National Building Code, 2005) which are Hot-Dry, Warm-Humid, Temperate, Composite and Cold (Refer to Fig. 1). The Composite typology combines the effect of hot and humid and hot and dry. Composite climates exhibit varying characteristics throughout the year, cycling between short periods of heavy rainfall and high humidity, and extended periods of intense heat and dryness. There is a third season, winter, which features chilly nights and dry, sunny days. The central region of India is covered under the composite zone. New Delhi, Kanpur, Ranchi, and Allahabad are a few cities that have this kind of climate. In the summers, these contexts receive direct sunlight and during the rainy season, the sunlight is not too bright, and they receive mostly scattered light. In the summer, it can get really hot during the day, between 32 to 43 degrees Celsius, and at night, it's warm, around 26 to 32 degrees Celsius. In winter, it gets cooler, with nights being cold, between 3 to 10 degrees Celsius, and daytime temperatures range from 10 to 25 degrees Celsius.

In dry and wet times, the relative humidity ranges from 20 to 25% and 55 to 95%, respectively. In this region, annual precipitation ranges from 500 to 1300 mm. During the monsoon, this area is subjected to strong winds from the southeast and dry, chilly breezes from the northeast. The state of Jharkhand, which is situated in the eastern region of India, has Ranchi as its capital. The research location, Ranchi District, is located along the Tropic of Cancer. The latitude and longitudes of Ranchi are 23.3* N and 85.3* E. Ranchi Plateau is situated at an average altitude of 900 metres above sea level, which is

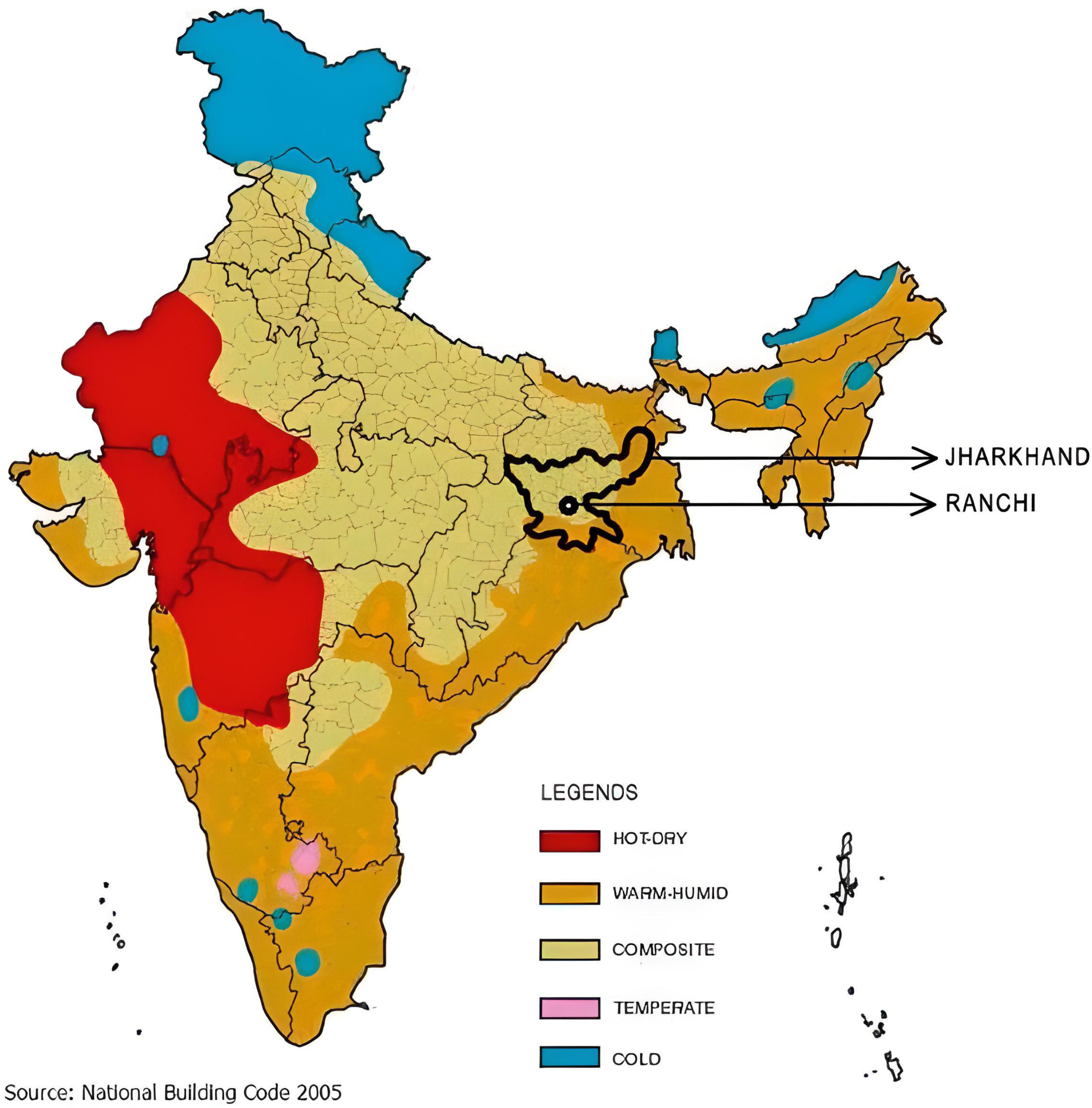


Fig. 1: (National Building Code, 2005) Classification of Climatic zones and the location of the Site.

a reasonably high altitude. According to the 2011 census (Census, 2011), Jharkhand has a sizable tribal population and 75.9% of its residents live in rural areas. As per the census 2011 (Census, 2011), 58.5 percent of dwelling units in Jharkhand have mud walls and 53.4 percent have clay-tiled roofs. All year round, the city receives high solar radiation and with moderately directed winds.

Literature Study

Traditional mud-based materials for constructing walls.
Mud is frequently used to build mud walls all across India because it can be used in a variety of ways and in conjunction with other materials. Table 1 lists some of the possible combinations that could be employed with other materials. The construction methods found in central India i e., Madhya Pradesh, Chhattisgarh and Odisha in the East, and in some Northeastern states as well include Daub (mud mixed with bamboo framework), Rammed earth mud walls and cob walls (built layer by layer). The majority of rural homes in these areas are made with mud walls and thatched roofs. The seven sisters, or the northeastern states of India, use mud, timber, and bamboo. Some northern and centrally located states' rural areas employ mud bricks and tiles for construction. In the southern part of India, clay bricks are used in many parts of Kerala and Mud bricks are commonly used in Pondicherry. The following table demonstrates different methods used to construct mud based walls mostly found in rural dwellings:

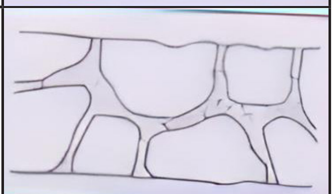
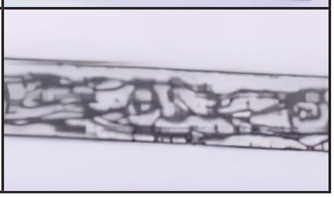
Combinations of Materials Used	Graphical representation
Cow dung Slurry with Compacted earth.	
Stone Masonry made with mortar of Mud	
Mud Mortar Coating on Poles and Twigs	

Table 1: Overview of Wall Building Materials Found in Composite Climate Zone of India (Bansal, 1988)

Knowing Mud as a building material and its Thermal Properties in detail.
Understanding material under various environmental circumstances is crucial to comprehend its thermal performance . This section examines the work that has already been done to describe the specific thermal characteristics of mud and their anticipated effects on the thermal performance that has been manifested so far. A study looked into people who live in traditional mud huts and their perspectives toward thermal comfort. According to their survey, 90.6% of people who live in mud homes say they are comfortable without artificial cooling or ventilation(Cooper,1998). According to Matthew Hall and David Allinson (2008) rammed earth typically has low thermal conductivity, measuring between 0.6 and 1.0 watts/mK. The following table (Table 2) lists some commonly used construction materials' thermal conductivity (K values) at moderate temperatures.

S.N.	Building Material	Thermal-Conductivity(k) (Watt/Metre Kelvin)
I	Brick	0.811
II	RCC (Mix 1:2:4 by weight)	1.582
III	Cement Mortar	0.951
IV	**Mud**	**0.6**
V	Brick Tile	0.681
VI	Cement Plaster	0.721
VII	Window Glass	0.815
VIII	G.I. sheet	60.47
IX	Thatch	0.35
X	Cellular Concrete	0.188

Table 2: Thermal Conductivity (K Values) of Common Building Materials at Moderate Temperature (Verma, 2004)

As per Gernot Minke (2005) the U value (Thermal transmittance) of the rammed earth wall which is 300mm thick reaches up to 2 Watt/Sq. Metre Kelvin, which is also known as its "Thermal Mass". It has a large thermal mass and great potential to store heat energy (Madhumathi, Vishnupriya and Vignesh, 2014). This means that they naturally control a building's interior temperature. Although they cannot easily stop the passage of heat energy, they can absorb and store it because of their high density. On the other hand, due to its density, rammed earth performs as a poor insulator. The interior relative humidity of the home is automatically regulated by rammed earth, leading to better air quality. During summers, the increased thermal mass prevents the heat from entering and shifts the thermal lag (Narayan, 2009). Insulated rammed earth walls offer excellent thermal resistance and surpass solid rammed earth buildings in terms of thermal mass. High thermal mass and low thermal conductivity can be achieved using rammed earth and rigid insulation.
By combining low thermal conductivity with high thermal

mass, a composite envelope can be created using rammed earth and rigid insulation (S, 2009).Comfortable dwellings have always been built with earthen resources. Buildings' fluctuating humidity and temperature are reduced to a minimum when the earth is incorporated (White, 2009).

Enhancing Mud's Insulation.

To boost the thermal insulation of mud-based materials, consider incorporating porous elements which include seaweed straw and light plant-based material. Insulation can be improved by adding material such as from plants, naturally and chemically formed mineral particles like lava, expanded clay, pumice and formed glass. Also, some of the waste products like wood shavings, grain husks, and sawdust, given their higher density makes them less effective as an insulator. Increasing the material's porosity enhances both its lightweight properties and thermal insulation. Notably, insulated rammed earth walls outperform solid rammed earth buildings in terms of both thermal resistance and thermal mass (Fix 2009). By combining high thermal mass and low thermal conductivity constructed from rammed earth and rigid insulation within a composite envelope, the U Values5 of these walls can be reduced to 0.33 Watt/Square metre Kelvin and 0.24 Watt/Square metre Kelvin, respectively only by utilising insulation that is either 50 mm thick or 75 mm thick (Stone, 2013).

Combining Mud and Bamboo.

Among the several methods for building mud-integrated bamboo walls, wattle and daub involve covering the bamboo structure with more mud than necessary, boosting the mud's insulation capabilities and promoting thermal comfort within. (See Fig.2)

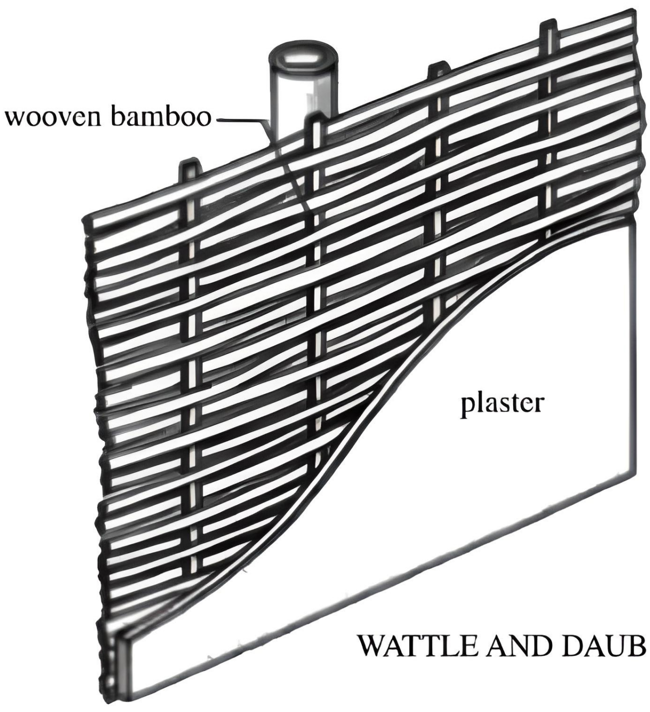


Figure 2: Wattle and Daub (Socrates, 2012).

Mud walls strengthened with bamboo provide insulation from heat and cold. Traditional buildings had walls > 50 cm thick, but mud walls these days are thinner because they are reinforced with bamboo culms that have been appropriately split in quarters and heated to bitumen. The horizontal and vertical strips of the reinforcing mesh are properly secured at the crossings using wires. A mixture is made by kneading rice husk, mud, cinder, little lime and water. This mixture is applied layer by layer while the bamboo grid remains in the centre.

Discussion:

Thermal Performances in Studied Mud-Dwelling.

Typical mud homes in Jharkhand feature walls that are 450 mm thick, constructed using the cob technique. This method entails applying layers of mud one over the other, gradually building up the wall's thickness (Fig. 3, 4, and 5). The following images show contextual examples and schematic sections:

Figure 3: Square Dwelling Unit 1. (Plan and Photograph).

Figure 4: Mud wall 450mm thick. (Source: Clicked by author).

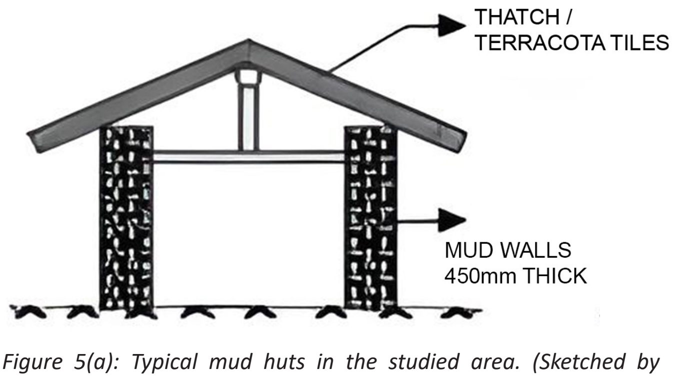


Figure 5(a): Typical mud huts in the studied area. (Sketched by author).

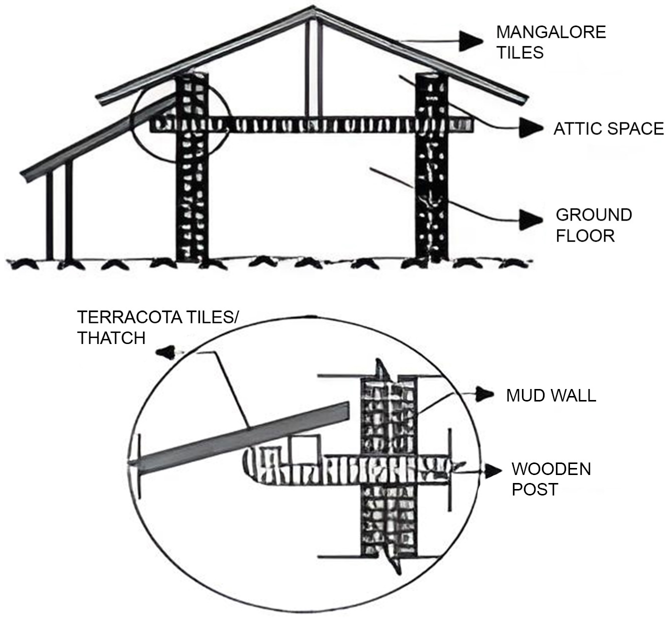


Figure 5(b): Typical mud huts in the studied area. (Sketched by author).

Observation: Fluctuations in temperature when studied for over 24 hours.

The authors conducted temperature measurements year-round, encompassing the hottest and coldest seasons determined from historical climatic data. These measurements were taken inside sample mud huts to gain a comprehensive understanding of how mud walls interact thermally throughout the year. The conventional mud home prototype's interior and exterior temperatures were measured and following were the observations:

1. In the summer and during daytime the thermal behaviour of the mud wall proved to be an advantage. But as night falls and temperatures drop, the temperatures within the hut continue to be high. When the outdoor temperature reaches 42 degrees Celsius during the height of summer, the temperatures inside all the buildings average around 35 degrees Celsius. Even though the outside temperature has dropped to 27 degrees Celsius, nighttime temperatures inside the hut are still high at roughly 35 degrees. The mentioned fact underscores the necessity of reducing thermal mass in mud walls during the warmer months to enhance cooling through night time ventilation.

2. The intrinsic thermal characteristics of mud, which permit thermal lag inside the mud dwelling, are useful in winter since they maintain nighttime temperatures above the cold temperatures outdoors. Due to the thermal time-lag factor, the interior temperatures do not decrease to that level. When the temperature of the outside drops to 3 to 4 degrees Celsius during the winter, the inside temperatures remain about 13 degrees Celsius.

Overall, it can be inferred that a thorough investigation of the thermal characteristics of Non- Stabilized Compressed earth blocks should be conducted and reported in ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) and the Indian building codes. IS: 2110-1980 Bureau of Indian Standards (BIS) talks about building cement soil walls in rural areas. Therefore under the BIS, in order to establish uniformity in mud construction procedures across the nation and make traditional mud architecture functional and modern, further rules for rural homes need to be introduced for the usage of compressed earth blocks and rammed earth walls.

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