# INFLUENCE OF DESIGN AND THERMAL CONDUCTIVITY OF BUILDING MATERIALSON INDOOR BUILDING TEMPERATURE

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**ABSTRACT**

*To find sustainable design solutions for energy saving and estimate the annual lifecycle performance of a building for thermal comfort in its functional phase.Various types of building bricks, especially building units i.e. bricks made up of various materials were tested for their thermal conductivitiesand the results were compared to draw an inference pertaining to thermal comfort.The study indicates that a decrease of nearly 30% to 40% in thermal conductivity is observed when materials like clay brick, flyash brick, and fire composite bricks were tested, with merelydecrease in dry density of 24%.. The study has also revealed that the orientation of the building, ventilation, window shading has positive effects on thermal comfort. Study indicates that wall to window ratio (WWR), significantly affects the performance of a building between 12 to 15 % and can directly or indirectly reducethe energy efficiency of the building by 25 to 30%.Energy demands in the buildings can be drastically reduced by using the material of low to very low thermal conductivity. Moreover small changes in the building orientation also help in making the building energy efficient.*

***Keywords:Thermal conductivity, Building Material, composite materials, orientation, window shading.***

## I. INTRODUCTION

Currently, the main concern is about the change in climate and the depleted resources in the world. It has been reported that with rising fuel costs, consumption and environmental concerns, it is the need of the hour to focus on clean, safe and sustainable alternative energy sources for power generation[1]. Construction sectors are one of the main factors for increasing global impact on environment as they consume high energy before and during habitation. The greenhouse gas emissions in this context has reached an alarming situation. Environmental conditions such as climate, pollution, change in weather, type of weather etc. affects the functional consumption of energy. Time has come to realize that less use of energy and more use of natural ventilation, proper orientation possible, optimum window to wall ratio (WWR), proper shading devices, proper use of thermal insulated materials can help people living in the building and will also reduce the environmental harm. Building materials for thermal insulation is the key aspectthat has been focused in the present study.

Firstly, the present work highlightsa review on various sustainable design solutions that can have positive impact on saving energy.

## II. EFFECT OF BUILDING ORIENTATION, WWR, MATERIAL AND GLAZING ON INDOOR BUILDING TEMPERATURE

Orientation of building is a very important factor which is directly applicable to the standards of thermal comfort within building. The factors that directly link to orientation are natural sunlight, solar rays falling on building, ventilation, angle of rays from the sun. Further, experimental results of various authors in literature have led to concrete conclusions as to which type of weather and what orientation is best suited for a building.With increasing demand of consumption of energy in houses in urban countries, it has become mandatory to adapt sustainable design methods to reduce the demand of energy, especially for cooling of building i.e. to lower down the indoor building temperature[1].

To achieve best possible results we need to promote best orientation design elements and to orient the building such that it receives least solar gain as possible. This will directly affect the thermal comfort of the whole building. Orientation of building should be decided in such a way that a cost efficient building is constructed. Amount of solar radiation falling on the building varies with its orientation, hence it also depends on the temperature zone that the building is placed in. Different temperature zones might have different requirements for orientation to achieve energy efficiency. Walls, windows and fenestrations are an important part of a building and also contribute to heat flow, in and out of the building which adds to the cooling load. In order to make the building more efficient it is important to consider the effects of windows and its glazing as well.

The study shows the effect of orientation, ventilationand window wall ratio (WWR) on thermal conduction in a sample room taken in East and West direction. Study compared two rooms (ventilated and unventilated) with different WWR to estimate the difference in indoor and outdoor temperatures[2].

1) Unventilated Roomwith WWR= 50%

2) Ventilated Roomwith WWR= 50%

3) Unventilated Roomwith WWR= 25%

4) Unventilated Rooms with WWR= 0%

5) Ventilated Room with WWR=0% and using Fixed Shading

Followed by the study it was found out that the building with WWR between 0% (with fixed shading) to 25 %, the indoor temperature is highly suitable for habitation in comparison to the outdoor temperature in ventilated conditions. Further, the rooms with East and West orientationscan provide better indoor comfort conditions as compared to rooms with North and South orientation. In India majority of the houses are one sided open and bounded by three side, making them less ventilated or unventilated. Constuction of houses with two side openings can enhance both WWR as well as Ventilation conditions within the buildings, which may be helpful in making indoor room temperature more favourable.

The effect of building orientation and window glazing on the energy consumption of HVAC System of a building for different climate zones was carried out[3]. The comparison of different cities stating different climate zones of India focusing on best possible orientation for building and the annual energy consumption in terms of space cooling and lighting was analyzed. The cities considered in the study depending on type of climate are-

1) Ahmadabad – Hot & Dry Climate

2) Bangalore- Moderate Climate

3) Chennai- Warm & Humid

4) New Delhi- Composite

The results of these four different cities were compared and it was concluded that for

- *Ahmadabad – Hot & Dry Climate*- North orientation is best suited and monetary benefit of INR 22 Lac per annum can be obtained.
- *Bangalore- Moderate Climate*-- North orientation is best suited with this orientation a monetary benefit of INR 18 Lac per annum can be obtained.
- *Chennai- Warm & Humid*- West orientation is best suited with this orientation a monetary benefit of INR 1.32 Lac per annum can be obtained.
- *New Delhi- Composite*- East or North orientation is best suited with this orientation a monetary benefit of INR 1.06 Lac per annum can be obtained

In order to reduce the indoor thermal discomfort thermal properties of different building materials such as Sand Crete, Mud, Brick and Concrete were carried[4]. The general properties of four types of building materials were studied depending on their width, conductance, effect of density and thermal transmittance values.

It has been found that the position of the sun plays an important role and the west side gets most intensely heated due to the position of the sun itself. Therefore, it can be suggested that certain reflective surface materials and taking into account the positioning of trees can reduce solar radiations effectively. Also, west orientation showed results with slight higher values of parameters than other three orientations inferring that the west direction is least favourable orientation. Studies onwindow shading shows[5]that **e**xternal shading technology is most effective and has the highest payback period among all retrofit methods. Experiments on 4 prototype buildings were performed in 5 cities representative of 5 typical climate zones over which different external sun shading methods has been applied namely, fixed shading (vertical and horizontal shading), flexible louver shading, flexible semi-transparent roller shutter sun-shading, and flexible opaque roller shutter sun-shading. The annual energy consumption data were also collected. Finally, a comprehensive evaluation was conducted to rate each method with a combination of economic and energy-saving rates.

Recommended shading –

- For office, hotel – flexible window shading(opaque)
- Residential – fixed shading
- Public- flexible window shading(opaque)

The types of shading devices and their comparison, for the most economical device keeping in mind the natural ventilation, solar radiation and glare are as follows:

1) Movable Opaque devices- blind curtains in rolls, awnings. They surely reduce the solar glance but have an obstruction for movement of air and the visibility.
2) Louvers- they come in both types fixed as well as adjustable. Provides shading to the building but also block the movement of air passage to a certain extend.
3) Fixed: Overhangs of *chajjas* provide protection to the wall and opening against sun and rain.

Shading of building is important to prevent it from solar radiations and keep the building cool. Certain mechanical devices can be employed to enhance the natural cooling process. Fans and evaporative coolers are extensively used. Cooling helps in cost cutting as the air conditioner is operated for a short time period. It is a very good practice as it reduces the consumption of energy and other resources.

Building equipped with Earth to air heat exchanger system using bamboo and PVE pipes in the duct system are also useful in reducing the influence of outdoor building temperature on indoor building temperature[6,7]. Further changing climatic conditions may drastically increase the outdoor average temperature conditions[8], which may leads to escalation in energy demand.In such conditions measurement of the thermal conductivity of different building materials and their selection on the basis of low heat transfer is the foremost factor that should be given priority. Thermal Conductivity of a material can be measured basically by two types of techniques, namely,*Steady state technique***-** material to be analyzed when it is in a state of equilibrium. The signals are constant but it takes time to attain equilibrium. *Non-steady state techniques***-**The measurement is performed during the process of heating up. The advantage is that measurements can be made relatively quickly. The use of Cigarette Butts (CB) in fired clay bricks prepared by partial replacement of 2.5%,5% and 10% of clay by weight in orginal brick material was also studied [9,10]. Similar type of studies and finding were also supported by other researchers as well.Size of the sample bricks were225 mm x 110 mm x 65 mm[11-13], their respective weights and volumes were calculated to illustrate the dry densities (Figure 1).


**Figure 1. Surface texture of bricks for mixes with 0 %, 2.5 %, 5 % and 10 % CBs[2]**

The experimental results revealed that the dry density decreased steadily with an increase in the amount of CBs. With the highest percentage of CB content added, thermal conductivity was found out to be least. Statistical analysis of the results showed a strong correlation between thermal conductivity and dry density. It was found out that with decrease in dry density, the thermal conductivity also decreases and the material act as a thermal insulator.

The four main types of instruments extensively usedto measure thermal conductivity are guarded hot plate, hot wire, modified hot wire and laser flash diffusivity. The techniques basically differ in sample size, testing time, capability and methodologies of measurement.

In the present study the guarded hot plate method has been used due to availability of device and ease of performance. Also, the method has proved to provide reliable results.

## III. METHODOLOGY

The methodology is aimed at testing building units i.e. bricks made up of various materials for their thermal conductivities. The test setup fabricated is similar in design to Hot plate method which is used worldwide for measuring thermal conductivity of the materials.

### 3.1 Experimental Setup

The experimental setup, consisted of a flame burner to act as the heat source for the material. Two alloy plates were used, one to be setup at the bottom of the material and other at the top. It was made sure that the surface area of the material is duly covered to maximum by a heat absorbent material (glass wool + black surface paper). The size of the brick sample was recorded as *230 x110 x76* mm. Thermocouples or portable thermometerswere suitably placed at either ends to note down the temperature on the warmer end and all across the length on the cooler end.Figure 2 shows the experimental setup for Clay brick, Fire Composite brick and fly ash brick.

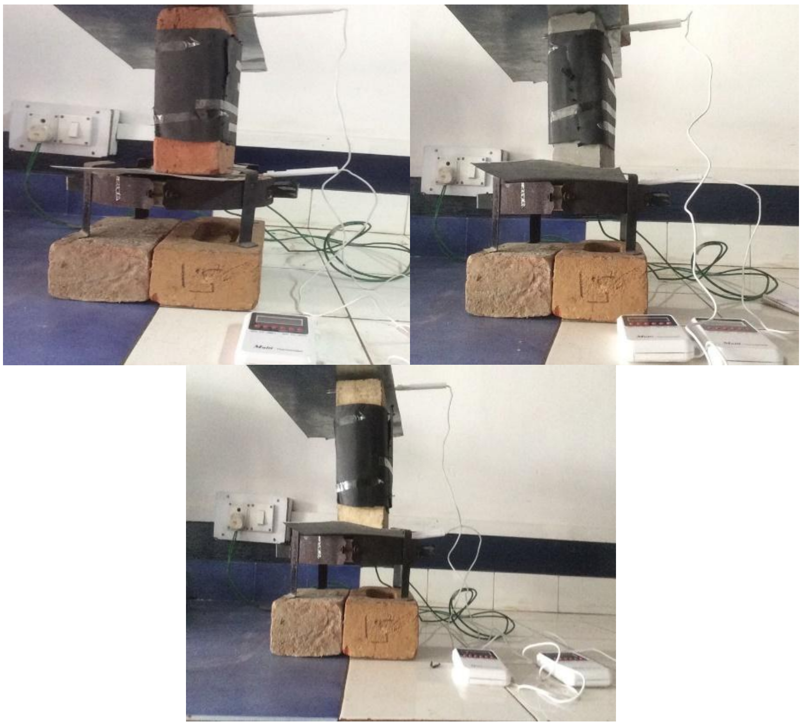

**Figure 2.Experimental setup for Clay brick, Fly ash Brick and Fire Composite Brick**

The aim of conducting the test was to measure the thermal conductivity of different building materials and comparing the same with theoretical data produced in the literature and their selection on the basis of low heat transfer. In this experimental setup, the lower plate was heated at40ºC of temperature and escalated up to 55 ºC in order to test the building materials at high temperature conditions that usually prevails in India during summers. In order to maintain nearly same temperature throughout the test, the heat source was regulated suitably. The reading in the thermocouple were noted on the warmer side and across length-wise on the cooler end of the guarded brick.The heat absorbent material helped in maintaining the heat inside the building unit and prevented consequent loss of the same in the surroundings. A sample of 10 bricks were tested of each material to remove any ambiguity in the results obtained due to non-homogeneity that could have been introduced in the material during its manufacturing. The consecutive readings has been tabulated and presented in the next section.

## IV. RESULTS AND DISCUSSION

Thermal conductivity ($\lambda$) is defined as the heat flow per unit surface area which is generated by a temperature gradient through the sample of certain thickness. Hence thermal conductivity can be found out using following expression:

$$\lambda = \frac{QL}{A\Delta T} \text{ [1]}$$

Where, Q= heat flow per unit surface area

A= surface area

$\Delta T$= temperature gradient

L= Thickness of the sample measured in direction of heat flow

Table 1, 2 and 3 shows the calculation of mean thermal conductivity for different types of bricks with varying densities.

**Table 1. Calculation of Mean Thermal conductivity of Clay Brick**

| Clay Brick | | | | |
|---|---|---|---|---|
| Sample | Temperature at hot end (°C) | Temperature on cooler end (°C) | Temperature Difference (°C) | Thermal conductivity (W/mK) |
| $CB_1$ | 55 | 24.7 | 30.30 | 1.19 |
| $CB_2$ | 55 | 25.1 | 29.90 | 1.21 |
| $CB_3$ | 55 | 25.2 | 29.80 | 1.21 |
| $CB_4$ | 54 | 24.9 | 29.10 | 1.24 |
| $CB_5$ | 54 | 24.8 | 29.20 | 1.23 |
| $CB_6$ | 55 | 25.0 | 30.00 | 1.20 |
| $CB_7$ | 55 | 25.3 | 29.70 | 1.21 |
| $CB_8$ | 54 | 25.1 | 28.90 | 1.25 |
| $CB_9$ | 54 | 25.0 | 29.00 | 1.24 |
| $CB_{10}$ | 55 | 25.2 | 29.80 | 1.21 |
| Mean Thermal Conductivity | | | | 1.22 |

**Table 2. Calculation of Mean Thermal conductivity of Fire composite Brick**

| Fire composite Brick | | | | |
|---|---|---|---|---|
| Sample | Temperature at hot end (°C) | Temperature on cooler end (°C) | Temperature Difference (°C) | Thermal conductivity (W/mK) |
| $FB_1$ | 54 | 20.8 | 33.20 | 1.09 |
| $FB_2$ | 55 | 21.0 | 34.00 | 1.06 |
| $FB_3$ | 55 | 21.1 | 33.90 | 1.06 |
| $FB_4$ | 55 | 21.3 | 33.70 | 1.07 |
| $FB_5$ | 54 | 21.0 | 33.00 | 1.09 |
| $FB_6$ | 54 | 20.7 | 33.30 | 1.08 |
| $FB_7$ | 54 | 20.5 | 33.50 | 1.08 |
| $FB_8$ | 54 | 20.4 | 33.60 | 1.07 |
| $FB_9$ | 55 | 20.7 | 34.30 | 1.05 |
| $FB_{10}$ | 55 | 20.9 | 34.10 | 1.06 |
| Mean Thermal Conductivity | | | | 1.07 |

**Table 3. Calculation of Mean Thermal conductivity of Fly Ash Brick**

| Fly Ash Brick | | | | |
|---|---|---|---|---|
| Sample | Temperature at hot end (°C) | Temperature on cooler end (°C) | Temperature Difference (°C) | Thermal conductivity (W/mK) |
| $FAB_1$ | 54 | 12.4 | 41.60 | 0.87 |
| $FAB_2$ | 54 | 12.6 | 41.40 | 0.87 |
| $FAB_3$ | 54 | 12.7 | 41.30 | 0.87 |
| $FAB_4$ | 55 | 12.9 | 42.10 | 0.86 |
| $FAB_5$ | 55 | 12.6 | 42.40 | 0.85 |
| $FAB_6$ | 54 | 12.3 | 41.70 | 0.86 |
| $FAB_7$ | 54 | 12.1 | 41.90 | 0.86 |
| $FAB_8$ | 55 | 12.0 | 43.00 | 0.84 |
| $FAB_9$ | 55 | 12.3 | 42.70 | 0.84 |
| $FB_{10}$ | 55 | 12.5 | 42.50 | 0.85 |
| Mean Thermal Conductivity | | | | 0.86 |

Table 4 enlists the values of densities of the three types of bricks used in the test. The results clearly shows that with decrease in dry density values of clay brick, Fire Composite Brick and fly ash brick from 2118 Kg/m$^3$, 1941 Kg/m$^3$ to 1611 Kg/m$^3$ respectively, the mean thermal conductivity also gets reduced.

**Table 4. Dry densities of different types of bricks**

| Type of Brick | Dry density(kg/m$^3$) |
|---|---|
| Clay Brick | 2118 |
| Fire Composite Brick | 1941 |
| Fly Ash Brick | 1611 |

## V. CONCLUSION

Type of building material used in a building, its orientation and window shading can minimize the indoor room temperature in countries like India for different WWR and glazing. It has been concluded that south orientation is best suitable for climates like that in the National Capital Region (NCR). It has been elucidated that the type of building with such orientation (longer surfaces facing north and south) is appropriate as it affords maximum solar heat gain in winter and minimum in summer. The theoretical and experimental studies conducted on building material namely clay Fire Composite Brick, fly ash brick and Fire Composite Brick, concluded that thermal conductivity depends on the density of the building unit or in other words on material it is made up of. The results show that it increases with increase in density. Fly ash brick being lowest in density has lowest thermal conductivity and is best suited to be used in buildings to bring down the inside room temperature. The study highlights that double or triple glazed window with low emissivity glass made of wood can decrease thermal transmittance value to great extent. The inclusion of these aspects leads to minimizing energy consumption in a building to lower down the indoor temperature in summers.

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