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# An Investigation of Design Considerations to Achieve Thermal Comfort in Warm Humid Climatic Zone of West Bengal

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***Abstract: This research paper presents the investigation of design consideration to achieve thermal comfort and the warm humid climatic zone of West Bengal is considered as the primary study area for the investigation. The varying thermal comfort behavior of humans in different climate conditions and seasons clearly demonstrates that the building design strategy must conform with the region of the building. In this paper, first studying the climatic characteristics of the warm humid region design factors are selected like building materials, cross ventilation, building orientation, roofing orientation, and materials, etc. After that, all those design factors are studied and the effect of all those factors on building in various conditions is observed.***

***Keywords: Warm Humid Climate, Thermal Comfort, Building Materials, U-value, Cross Ventilation, Building Orientation***

## I. INTRODUCTION

In a warm and humid environment, a building will acquire a condition of thermal discomfort. Perhaps air conditioning will be a solution to this problem of discomfort, but the process of air conditioning necessitates the use of electricity, which most people in underdeveloped nations cannot afford. Nowadays, To satisfy the rising thermal comfort expectations of the inhabitants, half of the total energy generated in the industrialized world is utilized to heat, cool, ventilate, and manage humidity in buildings (PK Latha, 2015). Humans seek to create a thermally pleasant atmosphere. Since ancient history, this has been seen in architectural traditions all around the world. It is still one of the most essential factors to consider while constructing modern structures (Sabouri, 2012). The major goal of this research is to look at various methods to improve and increase the efficacy of building energy efficiency techniques by looking at the components or elements that have a direct impact on thermal comfort.

## II. GENERAL OVERVIEW

The hot, sweaty, and sticky circumstances of the warm-humid climate, as well as the constant presence of moisture, characterize the climate. The air temperature remains reasonably warm, ranging between 21 °C and 32 °C, with little difference between day and night. (Koenigsberger). As a result, the use of innovative building materials and passive technologies in buildings may provide a solution for thermal comfort demands while also significantly reducing energy consumption, environmental effect, and carbon footprint of the global building stock. (PK Latha, 2015). Thermal comfort is defined in the ISO 7730 standard as being "that condition of mind which expresses satisfaction with the thermal environment". The human thermal environment is complex and cannot be described in terms of degrees. It can't be well characterized by permissible temperature ranges, either. It is a subjective sensation based on a variety of factors that varies from person to person even within the same location. The rate of heat transmission through a structure, which can be a single material or a composite, divided by the temperature differential across that structure is known as thermal transmittance, also known as U-value. W/m2K is the unit of measurement. The lower the U-value, the more insulated the material is. The U-value may be determined by taking the reciprocal of the total of the thermal resistances of the building elements. Using software U-value can be calculated easily. Once U-value is known it provides the thermal characteristics of that material.

## III.HUMAN BODY AND THERMAL COMFORT

The human body's adaptable reaction to climatic conditions demonstrates that it possesses intellectual behavior, capable of learning through the acclimatization and adaptation process. Learning and adaptive behavior were proven in human thermal regulation based on the requirement to disperse heat due to metabolic rate.

The human body's ability to control heat transmission is restricted. Insufficient heat loss causes overheating, which is known as hyperthermia, and excessive heat loss causes bodily cooling, which is known as hypothermia. Pain is caused by skin temperatures of >45°C or 18°C. The skin temperature linked with comfort during sedentary activities is 33–34°C and this temperature decreases as activity increases. (Zainazlan Md Zain, 2007)

Building energy efficiency refers to a structure's capacity to run and function with the least amount of energy possible. If comfort is a need for successful functioning, then comfort must not be sacrificed while using energy-saving methods. (Zainazlan Md Zain, 2007)

## IV. BUILDING MATERIALS AND BUILDING ENVELOP

Heat is transferred from buildings primarily by conduction, convection, and radiation through the building envelope, windows, and ceilings (FAO Document Repository, 2003). Marble, gravel concrete, and asphalt are strong heat conductors and should be avoided in exterior construction, whereas materials transport the least amount of heat from the outside to the interior. For a cool environment, wood can be used for the walls, ceilings, and windows. Windows also serve as a heat transmission medium. The heat is absorbed and trapped by the glass in the room. The interior temperature, and therefore the thermal comfort of the building's inhabitants, is also affected by mutual radiation between the wall and the ceiling. According to research, materials that reflect rather than absorb radiation and more easily release the absorbed quantity as thermal radiation result in a lower internal temperature (Michael Humphreys, 2002) (Andreas Christen, 2004).

In tropical climates, excessive heat transmission through the roof within the structure is one of the primary causes of thermal discomfort (Victor Olgyay, 2015). According to research by Kunzel et al., building materials should be non-hygroscopic and capillary-inactive (hydrophobic) since water may be a quiet culprit that damages a structure's thermal insulation layer (Kunzel, 1995). While modifying the composition and incorporating a mix of natural and synthetic materials, it is important to remember that the characteristics of the materials used must be based on the building's intended to function as well as the weather conditions to achieve maximum thermal comfort.

Stones, stone cladding, and earth-based bricks are the most commonly utilized materials for building walls in warm-humid climates. Sand-cement blocks are also widely utilized in warm-humid climates. Brick masonry with RCC frame structure is very commonly used as primary building materials. After brick timber is very frequently used. Timber construction like wooden flooring, the wooden partition wall are also used. Wooden doors and windows are seen almost in every building in the warm humid region of West Bengal. Glass is also very commonly seen in modern buildings.

Based on the thermal conductivity (l) and the specific heat capacity (c), the thermal diffusivity (D) and thermal effusivity (E) were determined, which are both essential features for non-steady thermal conditions. These two parameters are important characteristics for building comfort (Fgaier, 2015). When various layers of materials are used, all those parameters help to calculate the thermal conductivity easily.

The thermal capacity of the inner surface: it describes the capacity of a wall to absorb, store and restore calories. Essentially, it characterizes the internal thermal inertia (Fgaier, 2015). In the below, a few very common building materials and their properties are explained.

### *A. Cork*

Though cork is not a locally available material in Bengal, it can be used as thermal insulating material. Cork has been utilized as a hard-insulating material in Europe for decades. Cork granules are crushed at high temperatures and pressures to offer low thermal conductivity and are commonly used in North American and European structures for thermal and acoustic insulation in flooring, flooring-underlayment, interior or exterior wall buildings, and ceilings. Expanded cork may find use in tropical areas for providing insulation, particularly in the roof, depending on cost and local availability. (Denisselle, 1992)

### *B. Wood and Timber*

Wood and timber are considered to be strong thermal insulators and are appropriate for a variety of applications including windows, doors, roofing, and flooring (Goss, 1992). Wood's thermal characteristics are a function of moisture level and wood type since it is a hygroscopic substance. The way wood is treated and how it is used is largely determined by its intended use in a structure and the climate of the area. Due to the huge number of air gaps in the fiber-based panel, thermal conductivity values are lower than solid wood products such as fiberboard and hardboard panels manufactured from fibers or fiber bundles (ASHRAE, 2005). Wood and wood-based materials in the building envelope and furnishings, according to the Healthy Building Workshop 2000, manage the interior environment by regulating diurnal variations in indoor humidity. When compared to other construction materials such as glass, rubber, plastic, concrete, brick, and so on, wood has a larger heat capacity (1.6-3 kJ/kg K) and a lower density, making it ideal for usage as thermal insulators (Marcel Loomans, 2006) (Kordjamshidi, 2010).

### *C. Straw*

Straw has been used as a construction material for years and years since it is biodegradable and has no environmental impact, and it has become a popular technology in Mexico, France, Finland, and Australia. Because of the combination of the high isolative value of the bales and the thermal mass given by the thick plaster covering of the interiors, it behaves like good thermal insulation. A well-constructed straw-bale structure that has an air gap in between can offer good thermal performance (Garas, 2011). Straw is a thermally resistant substance that has a thermal resistance value of 6.51 to 7.82 W/m2 K for a 55 cm thick straw bale, according to Oak Ridge National Laboratory. This type of bale can be the most effective insulator when maintained dry. Plastered straw-bale construction, which is utilized in both load bearing and in-fill straw-bale construction, produces long-lasting, super-insulated buildings that provide thermal comfort (Pruteanu, 2010). In tropical climatic conditions, studies show that straw-bale buildings perform better thermally than other materials used for walls, but they have inherent disadvantages such as lower density for storing heat in the building fabric and low load-bearing properties, making them unsuitable for taller structures (Alhaddad, 2013). Although loose straw is extremely combustible, straw bales are compressed so tightly that any potential flame is deprived of air. To minimize moisture intrusion, finishing materials often used on straw bale walls (plasters and stuccos) are fire and mold-resistant (King, 1996).

### *D. Rockwool Insulation*

Due to its exceptional capacity to impede sound and heat, Rockwool insulation, which is made from actual rocks and minerals, can be utilized to produce a wide range of products and is widely employed in building construction (Itewi, 2011). Although rock wool is a superior conductor of heat, rolls, and sheets of this insulation are extremely effective at preventing heat transfer while also meeting the principles of sustainability, power protection, and recyclability, with the added benefits of being environmentally friendly and non-ozone depleting properties (Utochkina, 2014). Though this material is not locally available in West Bengal and it’s costly too, it can provide good thermal insulation.

### *E. Brick*

Bricks are one of the most significant high-heat-capacity building materials. With a thermal conductivity of 0.82 (W/m. K), clay brick has a high thermal mass performance (www.claybrick.org, n.d.). Internal temperatures of red brick structures remained very constant despite exterior diurnal variations, making it an excellent option for construction material, especially in hot regions. Fiber-reinforced mud brick, according to reports, keeps the inside temperature lower throughout the summer. Fly Ash Bricks (FAB) are also gaining popularity and are commonly used as building materials in green structures. FAB not only solves the problem of power industry waste disposal, but it also has superior thermal conductivities (0.90-1.05 W/m K) than traditional bricks (1.25 – 1.35 W/mK) (Ravi Rana, 2014).

### *F. Fly Ash Brick*

Buildings constructed with fly ash brick perform better in terms of thermal efficiency and provide a cooler indoor atmosphere than those constructed with clay bricks (Golden Makaka, 2006). In the years 2003-2004, the Central Public Works Department (CPWD) used 8.8 million fly ash bricks in all of their building projects in Tamil Nadu, as well as in other regions of India. Paki Turgut and Bulent Yesilata found that the physio mechanical and thermal performances of the rubber-infused bricks were 5-11 percent better than their traditional counterparts (Paki Turgut, 2008).

Alahabad et al. found that indigenous materials have better thermal characteristics than modern construction materials after running a simulation (Mousa Ahmed Alhaddad, 2013). Other natural items, such as raw or recycled sheep's wool, cotton rolls with additives like boric acid and flame retardants, Hemp mats, and fleece made from flax fibers, can also be used inside the wall or on the wall as a separate layer for good insulation. When cavity walls in wooden buildings need to be insulated, a loose-fill insulating material made from rye grain, rye pulp, and other additions can help (Hall, 2010).

## V. NATURAL VENTILATION

A case study was done by Kolawole Ajibola, a student of the Architecture Department of Obafemi Awolowo University, Nigeria, for a warm humid climate. That case study and further examination of the window/wall ratio reveals that 60 percent of living room areas have window/wall ratios of 30 to 50 percent, 16 percent have ratios of less than 30 percent, and 24 percent have ratios of more than 50 percent. In the bedrooms, 46 percent have window/wall ratios between 30 and 50 percent, 22 percent have ratios less than 30 percent, and 32 percent have ratios greater than 50 percent. 50 percent of the areas in the research are within the 30-50 percent range, 32 percent are below, and 28 percent are above. (Ajibola, 1997)

The window/floor area ratio analysis revealed that 24 percent of living room spaces, 15.5 percent of bedroom spaces, and 22.7 percent of studies have window/floor area ratios between 20 and 30 percent, 20 percent of living rooms, 1.7 percent of bedrooms, and 4.5 percent of studies have window/floor area ratios below 20 percent, and 56 percent of living rooms, 83 percent of bedrooms, and 72.8 percent of studies have window/floor area ratios below 20 percent. (Ajibola, 1997)

As virtually all of the structures are perpendicular to the entering wind direction, one would anticipate the window/wall area ratio and the window/floor area ratio to follow Chand's generalized ideas (I, 1976). The estimates of window/wall and window/floor area ratios, on the other hand, contradict this expectation. As a result, it's reasonable to conclude that the size and placement of windows in modern houses in a hot, humid region are mostly determined by the climate. (i) the users' aesthetic perception of the product; (ii) the typical window sizes available on the market; and (iii) the craftsmen's constructional constraints. All of this has little or no bearing on the window's role as a way of delivering adequate ventilation in a space. (Ajibola, 1997)

Despite the abundance of outside space, the results of the preceding research reveal that 25% of the spaces have single windows. There is no way to ventilate these rooms because there is no other outlet. Residents of these housing units expressed a need for additional bedrooms, greater storage, and a larger kitchen in previous research (Olufemi, 2014). Most inhabitants of most Government residential area houses have this mindset. The demand for greater space in a structure, as well as the normal restrictions on construction size per plot imposed by municipal planning rules, necessitate the provision of areas with single window openings. (Ajibola, 1997)

## VI. BUILDING ORIENTATION

Each structure has several orientations. In many regions, the best orientation would be north-south, with the long facade facing the equator and the facade sections facing east and west as little as possible. This is not always the case in warm, humid areas. (M.Haase, 2009). Simply positioning the structure to get the best ratio in the winter overlooks what occurs in the summer. Another goal is to keep incoming sun radiation to a minimum during the hot time (or summer). This will happen if the maximum summer radiation angle is 90 degrees from the maximum winter orientation. In many regions, if the two optimal orientations are not 90 degrees apart, a compromise must be made between the two goals. The degree of compromise of a building is determined by the quantity of heat and cold stress experienced at that particular place. This is computed as the difference between the number of degree hours above the comfort zone during the overheated phase and the number of degree hours below it during the underheated period. (Olgyay, 2015). Tropical and temperate regions benefit from natural ventilation, whereas subtropical ones do not. The possibility of comfort enhancements is limited. This should be taken into account while designing climate-responsive building envelopes. (M.Haase, 2009)

## VII. ROOF ORIENTATION, ROOFING MATERIALS, AND ROOF SURFACE COLOR

The orientation of the roof and roofing materials has a significant influence on a house with passive characteristics that are desired in warm humid climates to achieve thermal comfort. Clay tiles perform somewhat better heat-resistant material than cement fiber sheets as a roof covering material. Clay tiles are placed on the roof by interlocking each other. So, here between two clay tiles, the air gap plays an important role to reduce heat transfer as the air can freely flow. Light color roof surfaces (e.g., off-white) can produce indoor thermal conditions comparable to those of the insulation materials as they can reflect the maximum amount of thermal radiation. Insulation materials such as aluminum foil with or without polystyrene can considerably improve the thermal performance of a house. (Jayasinghe, 2003). According to the study, the influence of roof orientation on interior temperature conditions is negligible. But when it talks about the sloped roof, orientation plays an important role. As a result, beauty can be used as a decisive factor in selection. As a roof covering material, clay tiles are preferred over cement fiber sheets. Using aluminum foil with or without polystyrene over the ceiling can improve the situation because in between each material certain air gaps can help to decrease thermal conduction. Paint the roof's outside surface a light color like off-white, especially if the roof is made of cement fiber sheets. If the roof is made up of colored tiles, choose light colors. (Jayasinghe, 2003)

## VIII. CONCLUSION AND DISCUSSION

Thermal comfort is dependent on several climatic factors as well as on the design consideration taken for the climatic factor. If the correct design decision is taken in response to the climatic condition, the building may achieve thermal comfort up to a certain limit. Building orientation, material selection, building envelop color, roof orientation, and materials, cross ventilation all those factors have to be taken care of before designing a building. Particularly in the warm humid zone of West Bengal cross ventilation and building orientation are very important because of excessive humidity. Cross ventilation area ratio, its position, wind direction, etc. have to be taken care of. For materials thermal conductivity and U-value analysis can help to choose the correct materials and which side of the building which material should be used and thickness of the wall all those minor things also play a vital role to achieve thermal comfort in a warm humid region.

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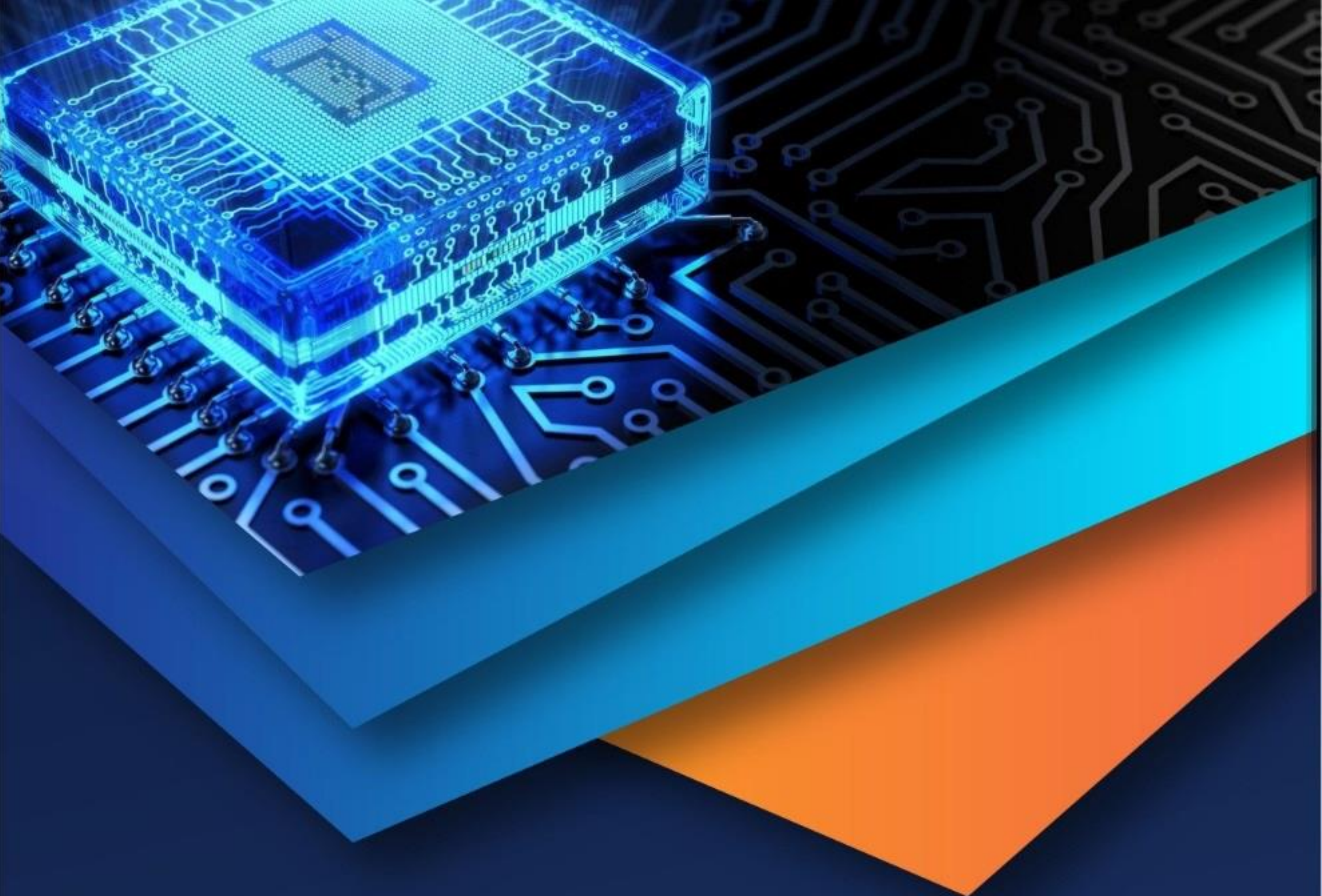

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