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Thermal Behaviour Of A High - Rise Residential Building- During Summer

Dr. M. Ponni[1], Mr N. Ravikumar[2]

[1,2]Assistant Professor, Department of Civil Engineering, Meenakshi Sundararajan Engineering College, Kodambakkam. Chennai, Tamil Nadu.

Abstract: **A** large area of land is required to build individual houses. But to build high-rise buildings smaller areas will be sufficient. A high-rise building consists of more than two floors. A building is an active system for thermal variations. Thermal variation in the outdoors brings out thermal changes in the indoors. The roof of a single-story building receives solar radiation directly and in the case of a multi-story building, the top floor alone receives it. Whatever the building type, the walls receive solar radiation directly. The heated roof or wall emits heat into the building space. In a high-rise building the indoor ambient temperature rises slowly to a steady state. Even if the outdoor temperature falls, the indoor temperature of the building does not decrease. There exists a time lag for the rise and fall of the outdoor temperature. This study measures the inside roof, inside walls humidity, and indoor temperatures of the different floors. It has been observed that the roof, walls, and indoor temperatures vary from floor to floor. The temperature rise affects the comfort of the inmates. Those who live in concrete buildings do not enjoy the comfort of living except the safety.

Keywords: Individual houses, High rise buildings, Roof temperature, Wall temperature, Indoor temperature, Comfort temperature, Thermal efficiency

I. INTRODUCTION:

A building is a human-made structure with four walls and a roof standing permanently in a place. A house or factory building comes in a variety of sizes, shapes, and functions. Buildings are built from available materials depending on the weather conditions, land price, ground conditions, specific use, and aesthetic reasons. Buildings provide shelter from the weather, security, living space, privacy, storing belongings, and getting comfortable living and working. A building as a shelter represents a physical division of a place of comfort and care from the harsh outside. A high-rise building has two or more floors above the ground level. The height of the high-rise building is attention-grabbing. Its elegant appearance flabbergasts the viewer. There is no formal restriction on the height of such a building or the number of floors, a high-rise building may contain. In a multi-story building, the frame is a three-dimensional structure or a space structure. Further, a building is subjected to various loads such as dead load, live load, lateral load, wind load, or Earthquake load. Too tall buildings are subjected to face more practical problems than others. Reinforced concrete buildings consist of floor slabs, beams, girders, and columns continuously placed to form a rigid monolithic system. Such a continuous system leads to greater redundancy, and reduced moments and dispenses the load more evenly. The floor slab may rest on a system of interconnected beams. The load-bearing capacity of the building depends on the size of the steel rods which are embedded in the concrete mixture. So a building envelope is a shield that protects the building.

The steel is a good conductor of heat. The reinforced concrete is a high thermal mass material. High Thermal Mass material (HTM) possesses the ability to absorb and store heat energy. HTM can store solar energy during the day and re-radiate it at night. HTM moderates internal temperatures concerning diurnal and nocturnal variations. The use of HTM materials in construction is generally not recommended in hot and humid climates due to their limited diurnal range. But population growth, urbanization, and land scarcity force high-rise buildings.

The top floor of the roof is subjected to direct heating by solar radiation during most of the hours of the day. The eastern side walls and the western side walls of the building are subjected to direct heating in the morning and evening hours respectively. The primary source of heat is the Sun. The buildings gain heat from solar radiation during the daytime. They reradiate heat not only indoors but also outdoors. The tropical climate of high-rise buildings retains more heat.

The primary material in the roof, columns, and beams are steel rods of different sizes, which is the major conductor of heat in the building shell. During hot days especially in summer, the heat absorption mainly takes place through the roof and is conducted to the steel rods in the roof. Then the heat flow is distributed to the other interconnecting steel rods. Whatever the heat absorbed it will be transmitted to the steel rods from the top to the bottom of the structure. Continuous absorption of heat keeps the top floor at a higher temperature than the other floors.

II. Literature Review:

The land requirement also shrinks for the builder. Hence the high rise buildings are predominant all over the world. Indian concrete roofs in single or two-storey buildings with 150mm thickness of reinforced cement concrete (RCC) and a weathering course (WC) having 75 -100mm thick lime brick mortar, account for about 50% - 70% of total heat transferred into the occupant zone and are in charge for the major portion of electricity bill in air-conditioned buildings [1]. As per ASHRAE (1990b) [2], energy resources are fundamental ingredients of all economic systems. Efficient use of energy is important since the reserve of our global energy resources is finite and depleting. Energy use in buildings involves parameters that are complex and diverse. The design of energy-efficient buildings is still not widely encouraged and suffers from a lack of appreciation for different reasons. Guided by market forces, many architects never bother to design buildings considering the climatic constraints and focus mainly on the aesthetic aspects, sometimes even following the negative effects of technology. The building sector plays an important role in the energy consumption. According to the Earth Trends Country Profile 2003, the Indian residential sector consumes about 201,000 MToe. (Million tons of oil equivalent), which is about 11% of the world's energy consumption in the residential sector [3]. It is noted that in the residential and commercial sectors, there has been a rapid increase in the consumption of electricity at a rate of about 13.2%. Research performed in Bangkok for improving thermal comfort in non-conditioned buildings in hot and humid climates reveals that the thermal performance of a multi-storied residential apartment is a matter of concern in warm and humid and hot and dry climates [4]. Heat transferred into the occupant zone is true for single-storey and top floors of multi-storeyed buildings [5]. Studies were reported on energy-efficient building envelope design for East Africa, where some basic energy-saving techniques have been recommended to reduce building energy consumption [6]. A comparative analysis has been done on the thermal performance of non-air-conditioned buildings with a vaulted roof and a flat roof under different climatic conditions [7]. A study performed on wall/roof thermal Performance differences between air-conditioned and non-air-conditioned rooms found that in an air-conditioned room, the most important physical property of the wall/roof is its thermal conductivity, which has to be as small as possible, while for the non-airconditioned room, the most important physical property is the thermal diffusivity, which also has to be as small as possible [8]. In urban areas, these multi-storied apartment buildings have a major share in residential accommodations. The individual flats /apartment units of these buildings differ from each other in respect of orientation, openings, shading, exposure to external surfaces etc. Leading them to respond differently in terms of thermal behaviour. The factors controlling the comfort within a building are indoor temperature, indoor humidity, and airflow. This field of research is important as the energy consumption of a building is associated with its thermal performance over the entire year and also the indoor thermal environment in the early summer has a carry-over effect of the previous winter due to the thermal inertia of the building envelope. Heat exchange processes in a building, are considered as a defined unit, with the outdoor environment [9].

A building in the tropics means a confrontation of construction and function with the intense climatic conditions. Tropical climate regions are characterized by high humidity, **excessive rainf**all, and considerable sunshine. (Auliciems2007) [10]. Typical features of tropical climate have a negative impact and a positive impact on the building design. The extreme effects are caused by the tropical climate through its climatic parameters such as temperature, solar radiation, relative humidity, rainfall, and the wind. It is an ideal medium state for rich of tropical plants and rainforests. (Al-Tammi & Syed Fadzil, 2011) [11] A favorable indoor environment depends on an understanding of the environmental factors, including building design and setting. A Healthy and comfortable indoor environment has become essential in the sustainable built environment. (Givoni, 1976) [12] Even though the full features of the climate are out of our control, the design of a building can affect its climatic performance significantly.

2.1 Building Form:

Oral and Yilmaz (2002) [13] reported that building form had a significant influence on the total heat loss of buildings. Conversely, the overall heat transfer coefficient (U-value) determines heat loss through the building envelope. Therefore, heat loss for different building forms should be determined by the U-value of the building envelope. The authors said that the shape factor (the ratio of building length to building depth), height, and roof type are the parameters defining building form.

2.2 Orientation

According to Givoni (1976), the effect of building orientation on indoor climate can be understood by taking into account two distinct climatic factors. Firstly, solar radiation and its heating effect on walls and rooms facing different directions. Secondly, ventilation problems result from the relation between prevailing winds and the building orientation. For example, in a building with insulated walls of light external color, and efficiently shaded windows, indoor temperature distinction depending on orientation may be ignored. Under these conditions, indoor climate dramatically depends on ventilation, and thus the orientation of prevailing winds is more critical than solar radiation patterns.

2.3 Thermal Mass

Moore (1993) [14] mentions that buildings having mass effect employ their thermal storage capabilities in four ways: by dampening interior daily temperature fluctuations; by delaying daily temperature extremes, by ventilating the building at night; and by earth, contact to provide seasonal storage.

2.4 Windows

According to Givoni (1976), heat gain through a window is much higher than that through an identical area of the ordinary wall, and its effect is felt rapidly without any time lag. This can be observed particularly in buildings with lightweight materials. On the other hand, the combination of shading devices and glass can optimize the thermal effect of windows. Another way of controlling the thermal effect of windows is to use of special glasses or glass treatments. Shading devices can be applicable externally, internally, or between double-glazing. They may be fixed, adjustable, or retractable.

2.5 Thermal Insulation

According to Straaten (2007) [15], a thermal insulator for buildings can be defined as any material blocking heat transfer and having a thermal conductivity value not exceeding 0.5 Btu/ft.H deg. F. per in. Thickness. Thermal conductivity value alone is not enough in choosing an insulation material.

Some researchers stated that Building form specifically the building envelope has a significant influence on the total heat loss/gain of buildings. Others mentioned that it is more related to the building orientation. According to a few, from a thermal point of view, the cube is the optimum building form that can be stretched to form a rectangle, and that heat gain or loss is higher in reticular forms. The majority agreed that buildings with a higher ratio of glazing area on their façade, which is more sensitive to climate conditions. However, it is possible to enhance it by getting all the benefits of passive design concepts.

Therefore, the principal feature that alteration has to take place for better energy performance is the envelope design. The building envelope modifications such as, are the ratio of window to the wall (WWR), different categories of glazing, and several kinds of shading systems. The effect of natural ventilation and building orientation is also investigated considering these design concepts at the early design stages; it is firmly believed that an acceptable indoor thermal environment is achieved with low energy consumption. Hence, the finding addresses the issues of thermal discomfort condition in a residential building at different scenarios of Window Wall Ratio (WWR) and corridor widths within the same building but with opposite orientations.

2.6 Comfort factors:

The comfort temperature determined by the author in the Hyderabad study [16] is 29.2˚C. The upper and lower limits of comfort temperatures are 32.5˚C and 26˚C. It indicates that those buildings that possess 29.2˚C indoor temperature will possess 100% thermal comfort.

The buildings having indoor temperatures above this will be losing their comfort. 30% relative humidity will be comfortable according to Ashare – National Research Council (Canada) Indoor Air Quality and Thermal Comfort in Open-Plan Offices, Construction Technology Update No. 64, October 2005.

Table 1 Comfort Temperature

Temperature	˚C	˚F
comfort temp	29.2	84.56
Comfort upper limit	32.5	90.5
Comfort lower limit	26	78.8

2.7 Energy Consumption:

Electrical energy is the primary energy utilized by the inmates of the apartment to run the fans, air conditioners, refrigerators, and other equipment. Summer energy consumption is more than twice the amount of winter utilization. For example, one of the flats used 340 units in winter and 720 units in summer.

III. Research Description:

A four-storied brick masonry residential building at Urapakkam, Chengalpattu, Tamil Nadu has been considered for the study purpose. The experiments were carried out exactly in Urapakkam, Chennai, and the coordinates are 12.8674^0 N and 80.0699^0 E. The experimental observations were recorded for one week. The study included the temperature measurements of the roof, walls, and indoors. The outdoor ambient temperature was obtained from the weather station. The aim was to find out the indoor temperature variations between different floors. Further to find out the percentage of comfort or thermal efficiency of the different floors.

Details Of the Building

The orientation of the building is north. It is a free-running building. The ground floor is left for car parking. The building has four floors and comprises 32 flats. The floors can be designated as G, G+ 1 or first floor, G+ 2 or second floor, G+3 or third floor, and G+ 4 or fourth floor. This apartment has a common area along the middle with flats on both sides. Each flat has an area of around 1200 square feet. The apartment is surrounded by a cultivating field and a lake on the opposite side. The solar radiation falls directly up to noon on the eastern side and the western side flats receive radiation in the afternoon without any obstruction. For this study temperatures were recorded only on the western side, middle flat on each floor. The observations were recorded at noon. The study was done for a week. A data logger was used to measure the indoor temperature and humidity. An Infrared thermometer (Fluke 59 Mini IR Thermometer) was used to measure the roof, floor, and four-wall temperatures. The indoor temperature and relative humidity were measured using Thermo - Hygrometer (Waco 220). The pressure was measured using barometer PHB 318.

Fig.1 Matrix Apartment

IV. Data Analysis and Results:

The measured values of G+1, G+2, G+3, and G+4 were used to draw bar diagrams.

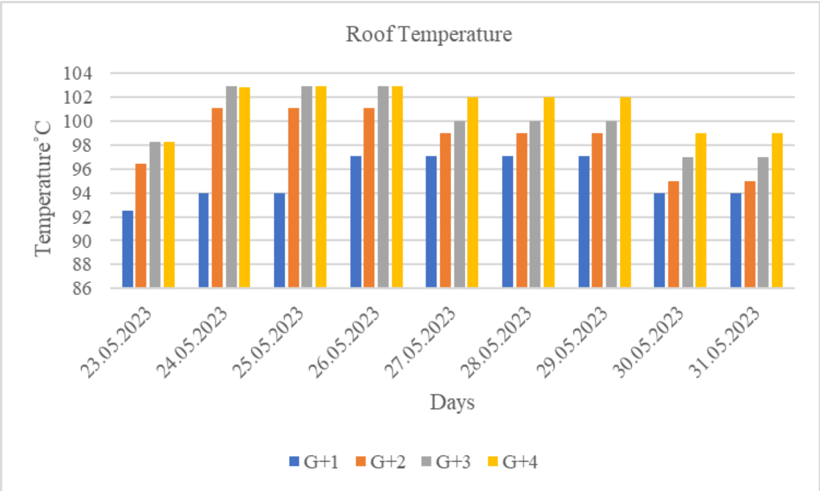

Fig. 2 Roof Temperature

Figure .2 Bar diagram Shows the roof temperature variations of different floors.

The roof temperature of the fourth floor was always high. The first floor showed low roof temperature.

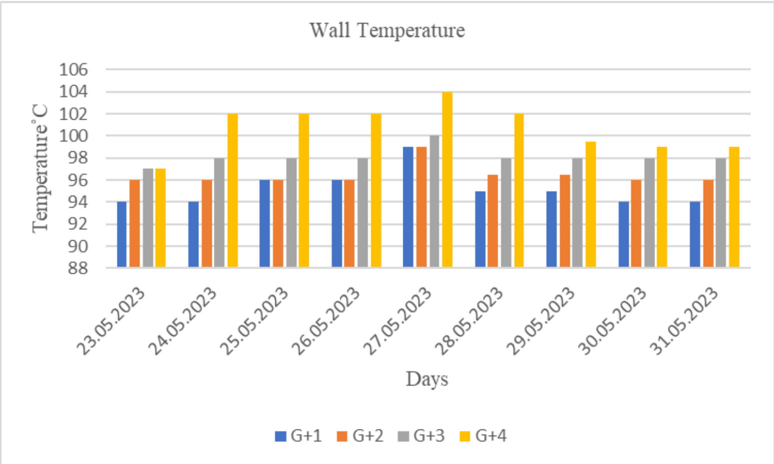

Fig.3 Wall Temperature

Fig.3 Bar diagram shows the temperature variation of average wall temperature of different floors.

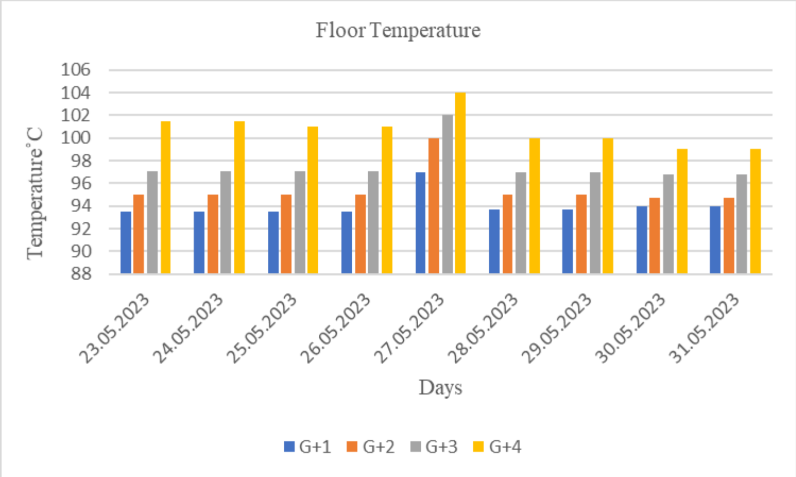

Fig.4 Floor Temperature

Fig.4 Shows the floor temperature variations or floor temperature variations among different floors.

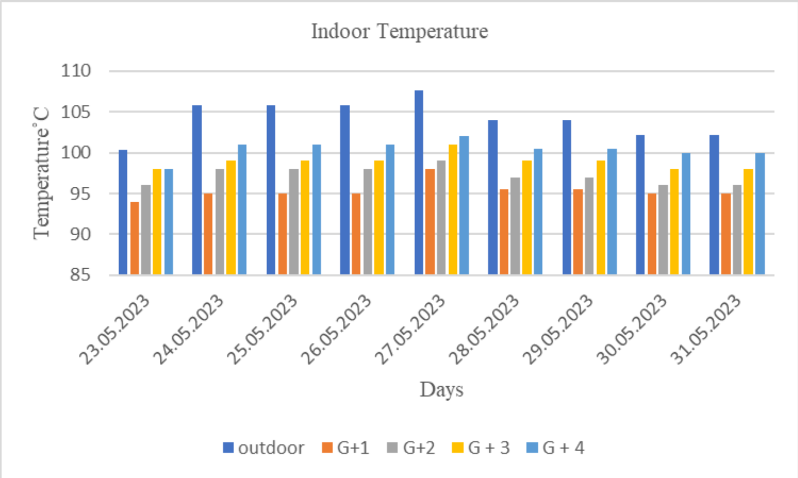

Fig.5 Indoor Temperature

Fig.5 Shows the room temperature variations or Indoor temperature variations among different floors.

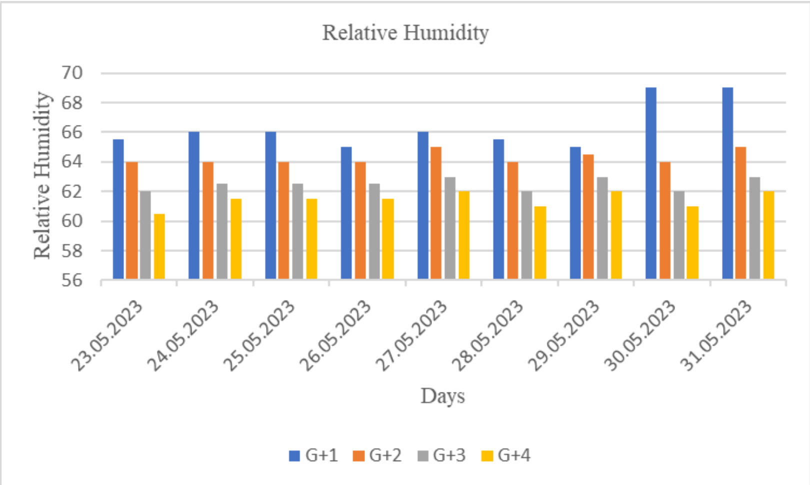

Fig. 6 Relative humidity

Fig.6 shows the Relative humidity variations among different floors.

Conclusion:

1) The Roof and wall temperature of the top floor is too high compared to other floors. The temperature of the roof and walls of the four floors is above the comfort temperature. That is in the discomfort region.

2) The room temperature of the top floor is higher than other floors. It is found that there is a variation between floors. It is observed that the room temperature increases from the ground floor to the top floor. The room temperature measured lies above the comfort level. That means the room temperature is also in the discomfort region

3) The relative humidity decreases from the ground floor to the top floor.

4) The measured indoor temperature also shows that it does not support comfort. A concrete building is not suitable for the summer season unless if it is not air-conditioned. In general, it can be concluded that concrete buildings are enhanced energy consumers in summer in the tropical region.

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