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Examination of the Relationship between a Building with Concrete Facia and its Indoor Thermal Environment in Umuahia, Abia State, Nigeria

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Abstract: The paper examined the relationship between a building with Concrete facia and its indoor thermal environment in Umuahia. Average temperature measurements of the roof environment for daytime and nighttimewere takenwith data loggers; an instrument calibrated to record and storetemperature every 8 hours between6.30 - 7.30 am, 2.30-3.30 pm and 10.30-11.30pm. The same instruments were used to measure indoor temperature of the same building.The average daytime temperature in the roof was 81.33°C and 24.26°C at night while the average daytime indoor temperature was 24.30°C and29.46°C at nighttime. 29.46°C is in discomfort zone, hence the indoor temperature of the building though within the comfort zone of 24.30°C in the day increased to 29.46°C, at night time an indication of heat gain. The roof average daytime temperature though 81.33°C fail to 24.30°C at night an indication of heat loss. Concrete is high in the thermal mass, it stores heat when heated by the sun and loses same at night to surrounding environment. This mechanism is ideal for arid or hot and dry climate where night is usually cold. The study found out that the heat lost by the roof was gained by the indoor environment and that thermal comfort was not achieved due to the heat gained. It recommended that buildings with concrete facia be designed to have vents at intervals to help reduce the heat stored in it and concluded by advicing architects to borrow and modify ventilation practices in colonial buildings within their neighbourhood if sustainable built up environment is to be attained.

Key words: Examination · Concrete facia · Indoor Thermal Environment

INTRODUCTION

Recent design and construction of buildings in Umuahia and its environment and in Abia State shows a fast and increasing demand for buildings with concrete facia. The trend has created street capes of buildings in concrete facia; a movement that has brought about redesigning and reconstruction of old buildings. This is because developers see concrete facia as a trending aesthetic component and not even the architect on whose shoulders the act of bringing man in harmony with his environment lies [1] considers the thermal properties of concrete and its impact on the indoor thermal environments before raising their designs.

Concrete facia is an architectural term for vertical freeze or band under a roof edge or which forms the outer cornice, visible to an observer [2]. Concrete facia when used hides the rafter projections carrying the eaves and like the eaves it extends out 300-500mm and replaces the visible eaves as featured in free gable roofs [3].

According to [4], the use of concrete facia in buildings is capital intensive and most times defeat the purpose of beauty for which most home owners in Abia State include it in their design briefs. [5], further noted that some other architectural defects arising from the use of concrete facia in warm humid locations such as in Umuahia, Abia State include the increase in structural load of buildings. He noted that concrete facia creates the use of multiple storm water drain pipework, which add to the construction cost and defaces the buildings, unless ducted or finished in conduit. The storm water drain pipes most often undergo recurrent repairs which also adds to maintenance cost of the buildings. However, [6] believe that concrete facia could be pleasant and that it protects the roof from storms, a feature which have encouraged its use in arid regions.

It is the view of this study that temperature in the roof environment of buildings with concrete facia is high, especially during the day, with the roof shell providing a storage tank. The paper therefore

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examined the relationship between a building with concrete facia and its indoor thermal environment in Umuahia.

[7], noted overheating to be the major challenge of climate design in warm and humid climates due to high relative humidity and little diurnal temperature difference, which is the cause of the overheating and accordingly [8] hold that the solar energy which is absorbed by the buildings envelopes, penetrate through openings to raise its indoor temperature.

Heat in a building's skin originates from three mechanisms: external heat, internal heat and ventilation. When solar radiation is incident on a building's façade, it gains external heat. Internal heat gain is produced inside the building due to heat input of occupants' electrical appliances and artificial lighting [9].

The human body's ability to measure thermal comfort is influenced by factors such as metabolic rate, clothing, energy radiation and heat loss from bodily surface [10]. Humidity, air temperature, air velocity and radiant temperature. A measurement and knowledge of these parameters help in identifying thermal sensation and variation of building and design make up assist in improving indoor thermal environment. It is important to design comfortable and healthy indoor environment because it is a criteria considered in sustainable building assessment.

Literature Review

Thermal Comfort Studies: Heat Movement in Buildings: [11] believe heat transfer is the basic mechanism of environmental effects on buildings and occupant's thermal behavior and that the most significant heat input into a building is through solar radiation, Both noted that in warm and humid climates, the solar radiation penetrates through the openings and that solar heat gain over the building envelopes during the day causes overheating in the building.

According to [12]; the amount of diffused solar radiation in tropical region is very high because of high content of water vapour in the air and the cloud cover in the sky. This excessive solar radiation affects the indoor thermal environment through direct radiation and absorption properties of materials. The penetration of direct solar radiation enter through buildings openings such as windows to heat up the internal surfaces. Absorption by building facades through conduction also transfer heat into interior spaces thus increase the indoor temperature [13].

Over the years, several definitions for thermal comfort have been given by various researchers. [14] defined thermal comfort as a state in which there are no driving impulses to correct the environment by behaviour. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) defined thermal comfort as the condition of the mind in which satisfaction is expressed with the thermal environment or as the express satisfaction within the thermal environment, in which 80% of the sedentary or slightly active persons find their environment thermally acceptable. (ANSI/ASHRAE, 2004). [15], later provided one of the simplest definitions of thermal comfort and defined it operationally as the range of climatic conditions considered comfortable and acceptable to humans. This implied an absence of two basic sensations of discomfort: a thermal sensation of heat and a sensation of skin wettedness.

From all the definitions, thermal comfort is achievable when temperature is under control and when at least 80 % of the sedentary or slightly active persons find their environment thermally acceptable. [16] underlines three variables that affect thermal comfort. These are environmental, personal and contributing factors. Thus, six parameters are necessary for thermal comfort assessment and calculations. These are: air temperatures, relative humidity, mean radiant temperature (which is equal to the air temperature), air velocity, metabolic rate and clothing insulation [17]. In most thermal comfort studies, temperature have been indicated as the most important parameter since it is temperature that actually determines how occupants feel within spaces. Most authors have confirmed this assertion. Air temperature is often taken as the main design parameter for thermal comfort. Hence it is essential for occupants? well-being, productivity and efficiency [18].

Thermal Mass: The thermal mass of a building material describes the ability of that material to absorb heat, store and later release it either outdoor or indoor. Thermal mass can delay heat transfer through the envelope of a building and help keep the interior cool during the day when the outside temperature is relatively higher [19]. When thermal mass is exposed to the interior, it absorbs heat from internal sources and dampens the amplitude of the indoor temperature swing [20]. This is particularly beneficial during warm periods, when the internal heat gains during the day is absorbed and help to prevent an excessive temperature rise and reduction in the risk of overheating [21]. A building with high thermal mass has the ability to absorb heat and provide a cooling effect which comes from the difference between the surface (radiant) temperature and that of the internal air [3] accounts that absorptance/reflectance will strongly influence the solar heat input. [5] agrees with [20] by asserting that porous materials with low specific heat exhibit low thermal mass effects. Additionally, good thermal conductivity and high reflectivity are also required for effective passive cooling by thermal mass.

Thermal mass can be defined as a material that absorbs or releases heat from or to an interior space. It can delay heat transfer through the envelope of a building and help keep the interior cool during the day when the outside temperature is high. Moreover, when thermal mass is exposed to the interior, it absorbs heat from internal sources and dampens the amplitude of the interior temperature swing.

Thermal mass can be utilized in several ways. The mass may be integral to the building envelope to provide direct cooling, or it can be remote, such as the earth under or around a building, through which fresh air is passed and cooled before entering the occupied space.

Traditionally, thermal mass is used in warm humid climates predominantly in public buildings of social and religious importance such as temples, whose heavy masonry envelopes also satisfy the need for durability. Appreciable reduction of the indoor temperature can be achieved in such buildings, with indoor air maxima about 3°*C* below outdoor air maxima having been observed in some cases; [11]. For modern buildings in warm humid climates, small-scale experiments; [8]; suggest that thermal mass can make an appropriate envelope material for spaces used primarily during the day, example living rooms, since it can help the interior cool during the occupied period. However, thermal mass is inappropriate for spaces used mainly at night, example bedrooms, as the mass usually releases heat to the interior during that period and may warm the space to an uncomfortable temperature.

To optimize the daytime cooling capacity of thermal mass, the mass should be ventilated at night to allow relatively cool night air to remove heat absorbed in the mass during the day.

Such use of nocturnal ventilation in conjunction with thermal mass is more common in hot dry climates, which relatively high diurnal temperature swings and low minimum night-time temperatures. Nevertheless, computer simulations by [4] [5] suggest that this technique may also have potentials; in warm humid climates where night-time temperatures are generally higher. A reduction in the indoor temperature of about 3-6°*C* below the exterior air may be achievable, depending on the local climate, the amount of mass, its distribution and the ventilation details.

Methodology: The building used for this study is located in Agbama Housing Estate, Umuahia North Local Government area of Abia State and was selected on purpose, because ofits design features which supported the study.

Data loggers were hung inside the roof shell of the buildings. One central data logger was hung at 1.5 meters from the King Post and sensors were hung at the four ends of the buildings at same heights. This was done to reduce the results from being influenced by friction. The sensors send data information to the central logger which was calibrated to read-off and store data at every eight hours, between the hours of 6.30-7.30 am when humidity is highest, 2.30-3.30 pm at the peak of the sunshine and 10.30-11.30 pm when the sun has set. In the same manner, data loggers were hung in the following indoor spaces of the study building, the family living room which occupies a central location and two bedroom in the east. The central location of the living room and the east location of the bedrooms limited its exposure to radiation which usually come from the west in the afternoon time. The study lasted for 3 months between 1st January to March 31st 2016. This period was to ensure unlimited hours of sunshine.

RESULTS

Table 1: Temperature of Roof in degrees Celsius

Month	Daytime	Nighttime
January	78	24.5
February	86	23.8
March	80	24.8
Total	244	73.1
Average	81.33	24.33

Table 2: Temperature of Indoor Environment in degrees Celsius

Month	Daytime	Nighttime
January	26.0	28.7
February	25.8	30.0
March	26.1	29.7
Total	72.9	88.4
Average	24.3	29.46

Analysis: The study revealed that the daytime temperature in the roof was 81.33°C, but inside the rooms in the building, the average temperature in the daytime was 24.3°C. Both temperature values changed at night time. At night, the temperature in the roof fell to 24.33°C and that of the indoor or room temperatures rose to 29.46°C.

The roof nighttime temperature seem to have replaced the comfortable daytime temperature of the rooms. While the roof lost heat, the indoor gained heat, a gain that created thermal discomfort, because the thermal comfort zone for this region stops at 26.0°C [13]. References raised in literature, supported this increase in indoor temperature of the study building. [8] affirmed that thermal mass increases the temperature of surrounding environment at night. [2] In support of thermal mass effect on buildings approved of its use in hot arid environments where heating is needed at night. The study was conducted in a warm humid environment, where high humidity and high temperature causes indoor discomfort, hence the increase in temperature from 24.3°C to 29.46°C is significant to create concern among home makers.

It is also important to note [7] observation about comfort and heat transfer, to appreciate the increase in temperature registered in the indoor of the study building. Both authors believe heat transfer to be the basic mechanism of environmental effects on buildings and occupant's thermal behaviour. Both believe that the principal source for this heat storage and transfer is radiation. In the case of this study, the roof gained heat through radiation and transferred same by convention.

RECOMMENDATIONS AND CONCLUSION

Heat generated in the roof environment was high because there was no venting, hence the paper recommends that buildings with concrete facia in Umuahia or locations with humid climate should have vents by ducting at the soffit of the concrete facia. The study challenged architects to design, construct and operate buildings to verify the recommendation for vents and the study concluded that if buildings with concrete facia are designed to have vents, it will provide thermally comfortable interiors and this will reduce the cost of energy used in cooling indoors in warm humid climates where high humidity and high temperature are known to exist. Lastly, it will support the crystallization of green and sustainable environment.

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