Middle-East Journal of Scientific Research 28 (2): 98-102, 2020
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2020.98.102

Improving Indoor Thermal Comfort of Concrete Facia Buildings In Umuahia, Abia State Nigeria

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Abstract: In a yet to be published study the author measured the heat stored in the roof of a concrete facia building with an aim to finding its relationship with its indoor environment. It was discovered that the high temperature of the roof 81.33°C affected the indoor thermal environment negatively, as it raised its temperature to an uncomfortable degree of 29.46°C. The study recommended that concrete facia buildings copy the venting technology in colonial buildings, to reduce the temperature in the roof, which gets transmitted into the indoor environment of the same building at night to increase its temperature. As a follow up to this recommendation, by Alozie a concrete facia model building was designed with ducts in its soffit in 2016 and commissioned in November 2018. The indoor environment of the new building was subjected to thermal measurement between the months of January 1st and March 31st 2019. The result revealed that the temperature of the indoor environment dropped to a comfort zone of 24.73°C. The study therefore recommended that since venting reduced the temperature of the indoor environment, that architects and developers key in to its application in the new concrete facia buildings they design and construct sand the old ones they renovate in Umuahia and elsewhere with similar climate. The study concluded that the application of such innovation in the design and construction of concrete facia buildings will reduce energy consumption in homeswhile crystallizing energy efficient and sustainable green environment.

Key words: Indoor environment · Thermal Comfort · Concrete facia and Vents

INTRODUCTION

Overheating is the main problem of climatic design in warm and humid climates. Compared to hot dry areas with high temperature, warm and humid climate has high relative humidity and small diurnal temperature difference, which is the cause of overheating [1]. Solar energy absorbed by the building envelops, penetrates through openings to raise the indoor air temperature. Each material has different thermal property, which act alongside heat from solar energy to determine the temperature of indoor environments [2].

Heat in a building skin originates from three sources and there are, external heat, internal heat and ventilation. Solar radiation on building envelope is the source of external heat gain. Internal heat gain is produced inside the building due to heat input of occupants, electrical appliances and artificial lighting [3]. And the human body's ability to measure thermal comfort by making judgments of indoor thermal state, that is whether the space is too warm, too cold, hot, very hot or thermally comfortable.

According to [4], human thermal comfort is influence by many factors such as metabolic rate, types of clothing worn, energy radiation and heat loss from the body surfaces. Both further stated that there are four classical thermal environmental parameters to predict human thermal sensation and they are, humidity, air temperature, air velocity and mean radiant temperature.

Measuring these parameters help to identify the thermal sensation and variation of building design help to improve the indoor thermal environment. It is important therefore to create comfortable and healthy indoor environment which is one of the criteria considered in sustainable building assessment tools.

Recent design and construction of buildings in Umuahia and its environment in Abia State shows a fast and increasing demand for buildings with concrete facia.

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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 [5] considers the thermal properties of concrete and its relationship with its 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 [6]. 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. [7]

According to [8], 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. [9], 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 construction cost and also defaces the buildings, unless ducted or finished in conduit. The storm water drain pipes most often undergo recurrent repairs which add to maintenance cost of the buildings. However, [10] 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 examined the relationship between a building with concrete facia and its indoor thermal environment in Umuahia and ways to improve indoor thermal comfort in concrete facia buildings in the area.

Literature Review

Thermal Comfort Studies: Heat Movement in Buildings: Over the years, several definitions for thermal comfort have been given by various researchers. [11] 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. [12], 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 wittedness.

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. [13, 14] 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 [15]. 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 [16].

[17] 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 [18]; 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 enters 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 [19].

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 [20]. When thermal mass is exposed to the interior, it absorbs heat from internal sources and dampens the amplitude of the indoor temperature swing [21]. 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 [3]. 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. [2] accounts that reflectance will strongly influence the solar heat input. [5] agrees with [6] 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; [16]. For modern buildings in warm humid climates, small-scale experiments; [17]; 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, with relatively high diurnal temperature swings and low minimum night-time temperatures. Nevertheless, computer simulations by [6, 7] 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 study is located in Agbama Housing Estate, Umuahia North Local Government area of Abia State. The building was designed to a brief that presented the opportunity to experiment the finding and recommendation of an earlier study by same author. It was completed and commissioned for use in November 2018. (Figures 1 & 2), shows abridged sketches of the roof plan and the section showing air inlets and out lets around the building Permission to use the building for study was granted in December 2018 and the study commenced on 1st January 2019 lasting to 31st march 2019.

Data loggers were hung inside the roof shell of the building. 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 in like manner with the earlier study by Alozie. 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 bedrooms 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. Radiation increases indoor temperature. The study lasted for 3 months between 1st January to March 31st 2019. This period was to ensure unlimited hours of sunshine.

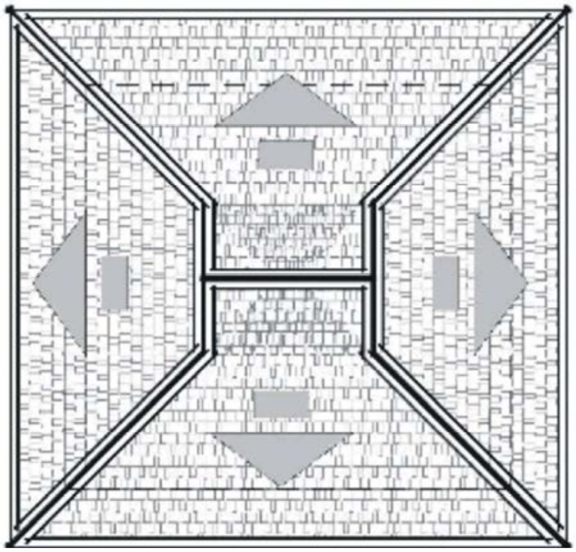

Fig. 1: Plan of a concrete facia roof with ducts to let in air and outlet at the rooftop

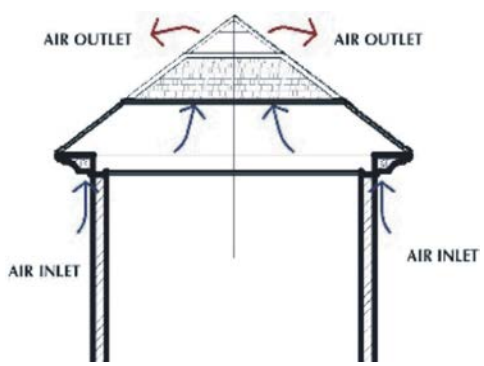

Fig. 2: Section through of a concrete facia roof with ducts to let in air and outlet at the rooftop

RESULTS

Table 1: Temperature of Roof in degree Celsius

Month	Daytime	Nighttime
January	48	24.5
February	46	23.8
March	44	24.8
Total	138	73.1
Average	45.66	24.33

Table 2: Temperature of Indoor Environment in degree Celsius

Month	Daytime	Nighttime
January	26.0	24.7
February	26.8	25.0
March	26.1	24.5
Total	78.9	74.2
Average	26.3	24.73

Average: The study revealed that the daytime temperature in the roof was 45.66°C, against the preceding study's value of 81.33°*C* and the night time remained low at 24.33°*C*. The indoor temperature of the model building in the day remained low and comfortable at 26.33°*C*, but came lower to 24.73°*C* at night, against 29.46°C recorded in the case of concrete facia building without venting, or inlet and outlet for air.

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 such as Abia State should have vents by ducting at the soffit of the facia. The duct is installed to enter into the roof shell.

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 of concrete facia buildings in warm humid climates where high humidity and high temperature are known to exist. Likewise it will assist in the crystallization of green and sustainable environment.

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