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Assessment of Indoor Thermal Comfort of a Courtyard Building in Umuahia Urban Environment of Abia State, Nigeria

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Abstract: The study assessed thermal comfort condition of a courtyard building in Umuahia. Two out of the three flats were selected by balloting. The Living rooms of each of the 2 selected flats automatically became part of the sample size while further balloting to choose one from the two bedrooms in each flat was carried out. At the end, the bedroom after the Living room in Flat A was chosen and in Flat B, the second bedroom between the first bedroom and the conveniences was chosen. Both bedrooms are shadowed on both sides by building spaces. These became the sample for indoor thermal comfort measurement.Digital thermometers (data loggers) were used to measure indoor temperature conditions of the spaces between September 15th and November 15th of 2019. Thermal comfort wasdetermined using the Effective Temperature Index (ETI), this provides a comfort range of 18 to 26°C for warm humid climates,in which Umuahia falls. Two bedrooms and one living roomwere comfortable while theliving room thatopened to the West was 28°C. A, 2°C deviation is enough to cause thermal discomfort. The study revealed that the courtyard created environment for air flow which helped in ventilation,and also in providing comfortable thermal interior and daylighting. The paper underscored the need for Architects to include courtyards in their designs. It highlighted the potentials of courtyard in developing a sustainable energy efficientbuilding sector. The paper remarked that this will help check global warming and climate change.

Key words: Courtyard · Energy Efficiency · Lighting · Thermal Comfort and Ventilation

INTRODUCTION

The need for sustainable built environment has created a consciousness for bioclimatic design. Bioclimatic architecture refers to the design of buildings and spaces (interior and exterior- outdoor) based on local climate, aimed at providing thermal and visual comfort, making use of solar energy and other environmental sources. This is good a development for future as there have always been concern for sustainability in the issues of energy and greenhouse gas emissions which often results from the use of mechanically driven appliances or active means for ventilation.

The increasing demand for energy in buildings need for ventilation, lighting and thermal comfort awakened the search for alternative means. The answer to this alternative means is passive concepts.

Climate change and increasing temperature has brought an increase in the number of air-conditioners needed to improve indoor thermal comfort in homes and improve production in work places. This increasing energy need have put very high premium on its cost because buildings account for more than 40% of global energy consumption [1]. Air-conditioners consume a lot of energy and also create negative impacts on the environment [2]. This energy cost and negative impacts accompanying it, calls for alternative methods of attaining indoor thermal comfort in buildings. One of such alternative means, which is cost free, harmless, enhances thermal comfort, provides ventilation and lighting in buildings is the use of courtyards.

Courtyards are common elements in buildings found all over the world which have been used by both ancient and contemporary architects as a typical and traditional building feature, which is defined as an open to sky area, enclosed built space. Courtyard an ancient architectural element in planning and design is gradually regaining popularity among architects in recent time because developers now enjoy feeling the outdoor from the indoor [3].

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In architecture, courtyards make perfect sense, as they provide the residents of a home private outdoor space, which is secure and suitable throughout the day. With its natural ventilation, a courtyard helps the house stay appropriately warm or cool without the need of air conditioners or heaters. In architecture, courtyards are design elements which connect interior and exterior spaces [4].

The open air oasis of courtyards is rare and desirable feature, especially in dense cities as it provides a multifunctional extension of living space, which is ideal for entertaining, gardening, yoga and star gazing, right in the middle of a restless city. Unlike a yard, the courtyard carved out in the center of a building provides a private tranquil space for homeowners, or buffered space for apartment dwellers in courtyard apartments [5].

The architect finds the courtyard helpful in resolving circulation, ventilation, lighting and thermal comfort challenges. Courtyards have spatial attributes which changes with different times of the day and seasons and this inspires the architect to experiment with the spatial and temporal dimensions in architecture. This study assessed the indoor thermal conditions in a building with courtyard in Umuahia urban environment.

Literature Review

Ventilation Studies: Ventilation moves outdoor air into the building or a room and distributes the air within the building or room. The general purpose of ventilation in buildings is to provide healthy air for breathing by both diluting the pollutants originating in the building and removing the pollutants from it [6]. Ventilation in buildings have three basic elements: Ventilation rate, which is the amount of outdoor air that is provided into the space and the quality of the outdoor air. Airflow direction which is the overall air flow direction in a building, which should rise from clean zone to dirty zone and air distribution or airflow pattern. The external air should be delivered to each part of the space in an efficient manner and the airborne pollutants generated in each part of the space should also be removed in an efficient manner. There are three methods that may be used to ventilate a building: natural, mechanical and hybrid (mixed –model) ventilation [7].

Natural Ventilation: Natural forces (e.g. winds and thermal buoyance force due to indoor and outdoor air density differences) drive outdoor air through purpose-built, building envelope openings. Purpose- built openings include windows, doors, solar chimneys, wind towers and trickle ventilators. Natural ventilation in buildings depends on climate, building design and human behaviour [8]. Advantages of natural ventilation include provision of a high ventilation rate; it is more economical due to use of natural forces and large openings. Natural ventilation is energy efficient especially when heating is excluded. It could provide high level of daylight.

Mechanical Ventilation: Mechanical ventilation is an integral part of Heating, Ventilation' and Air Conditioning (HVAC). It is the movement of air from one space to another as well as supply of fresh air into the air conditioned space. Mechanical ventilation assist in controlling the humidity, contaminants and general air quality.

Hybrid or Mixed Ventilation: Hybrid ventilation relies on natural driving forces to provide the desired design flow rate. It uses mechanical ventilation when natural ventilation flow rate is too low [9].

Natural Ventilation in Courtyards: [10] identified major effect of the courtyard to be the ability to provide better ventilation to building's interior by having the space for exchange of air between indoor and outdoor environments. The effectiveness of the courtyard in providing ventilation is because it makes use of both stack and wind forces to generate airflows through the room spaces adjoining to the building well. During summer, the stack force can be inactive while the walls act like the chimney for venting warm air out through roof openings.

Thermal Comfort Studies: Thermal comfort is defined by American Society of Heating, Refrigeration and Air –conditioning Engineers [11] as the condition of mind which expresses satisfaction with the thermal environment [12] went further to quantifying comfortable thermal environment as one in which 80% of the sedentary or partly active people in it accept to be thermally comfortable.

There are six main factors considered when defining thermal comfort conditions and there are, air temperature, radiant temperature, air speed, humidity, metabolic rate and clothing [13]. Thermal comfort indicator are generally based on Prediction of Percentage Dissatisfied (PPD) and Predicted Mean Value (PMV). PMV is an index that predicts the mean value of the votes of a large group of persons on seven thermal sensation scales, while PPD is

an index that establishes a quantity prediction of the percentage of thermally dissatisfied people which is determined from Predicted Mean Value [14-16], has the temperature range of 18 to 26 degrees Celsius (18-26°C) as the comfort zone for locations in warm humid climates. Umuahia as noted in [17] is in warm humid climate, hence the range applied.

Indoor thermal discomfort results from increase in temperature and a solution may be to increase air flow through ventilation. [18]. Ventilation which has been defined earlier as the replacement of used air by fresh one could be enhanced in buildings with courtyard because it enables the architect to achieve window openings in opposite directions, usually referred to as cross ventilation. This indeed provide for less usage of active energy and saves energy which incrementally build up to energy sustainability.

Natural Lighting: Lighting is an important issue in the context of planning and sustainable development. Lighting scheme whether natural or artificial can be costly and difficult to change if they are found to cause problem in its initial stage of design in building. Light schemes have been found to provide vital benefits to users but not all openings to let in natural light or modern artificial lighting is suitable in all situations and locations [19]. Natural light is an effective dynamic tool for expressing the quality of living space.

Artificial Lighting is not a natural component of the environment. Its production is aimed to replace natural lighting when it is not enough, such as in buildings with insufficient windows or at night. Artificial lights usually originate from lamps. Despite high performance inventions, no artificial light equates the dynamics of natural light [20].

Buildings in general and commercial buildings in specific, the use of artificial lighting is considered a key problem that can lead to bankruptcy in energy. As it affects cooling and heating loads requirements of the building (Department of Energy, 2004). [5] noted energy consumption by artificial lighting to amount to 25%-40% of total energy consumption hence the call for courtyards, not only for cooling the house, but also in providing natural lighting during the day time and minimize lighting loads.

Courtyard as Means for Sustainable Energy Efficient Buildings: Courtyards were developed mainly in response to climatic requirements. The residents of such climates utilized the courtyard to serve as a collector of cool air at night and a source of shade in the daytime [7].

Courtyards are not new concepts in architecture; rather it is one of the oldest forms of residential dwelling development in history of man having been used by many urban and medieval civilizations. Courtyards are believed to be able to improve the natural ventilation performance of buildings [12]. They are transitional zones which improve thermal comfort conditions by modifying the microclimate around the building and by enhancing the airflow in the building [5]. One of the objectives of courtyard is to introduce the outdoor into the heart of the buildings core, as well as optimize the climate source.

Passive design strategies are aimed towards sustainable energy efficiency in buildings. Energy efficient buildings, afford indoor thermal comfort and prolonged application of it brings about sustainable built environment. Application of courtyards in buildings can contribute meaningfully towards achieving passive buildings with high energy efficiency [10].

[11, 12] underscored passive and low energy architecture as strong design strategy to bring cooling into buildings. [15] affirmed that employing passive measures reduces the much dependency on active measures to energy use in buildings. Dependency on active energy sources Akande argued is because most residents have experienced constant thermal performance failures resulting from high indoor temperature. He concluded that courtyards remain one of the ideal elements to mitigate environmental issues resulting from high temperature, ventilation, thermal discomfort and poor indoor air quality. Which have continually become disturbing impacts of global warming and climate change.

[7, 8] opined that courtyard is microclimate modifier, in dwellings due to its capability to moderate high temperature, channel wind and regulate the amount of dampness, hence courtyard as good passive strategy for attainment of Passive and Low Energy Architecture(PLEA), cannot be overlooked.

Study Building: The building is located in the World Bank Housing Estate, Umuahia. Built twenty years ago on a plot of 20 x 25 meters. It has a central courtyard and three blocks of flats of two bedrooms each. The buildings' orientation enabled the bedrooms toavoid the West, which is often open to solar radiation, however one of the living rooms did not.

Methodology: Similarly data loggers were mounted at the verandah of each of the three flats to measure the outdoor temperature and humidity. The verandah provided shade for the instrument. Secondary data was collected from

Table 1: (Flat A)-Indoor Temperature and Humidity Measurements

	Living Room		Bedroom	
Months	Temperature in°C	Humidity in %	Temperature in°C	Humidityin %
Sept	28.4	78	25.0	78
Oct	28.6	80	25.2	76
Nov	28.2	82	24.8	71
Average	28.3°C	80	25°C	75

Table 2: (Flat B)-Indoor Temperature and Humidity Measurements

	Living Room		Bedroom	
Months	Temperature in°C	Humidity in %	Temperature in°C	Humidity in %
Sept	26.1	78	25.7	66
Oct	25.9	74	26.0	68
Nov	25.3	69	25.1	76
Average	25.8°C	73	25.6°C	70

AGROMET, a subsidiary of NIMET at Agricultural Research Institute, Umudike. The data loggers were calibrated to take readings and store off at every eight hours beginning from and between 7:30-8:30 amwhen the humidity is highest, 2:30-3:30pm at the peak of the sun and 9:30-10:30 pm when the sun had set. Residents were also interviewed

The study lasted for three months, between 15th September-15th November 2019. The study period was scheduled to capture both rainy and dry seasons.

Results and Analysis: The indoor temperature of both bedrooms in flats (A and B) was 26°C and 25.6°C respectively. Both results remained within the comfort zone index of 18°C to 26°C for warm humid climates using the Effective Thermal Index (ETI). Umuahia is in a warm humid climate. Living room (A) recorded 28.3°C, a deviation of 2.3°C from the comfort zone. This deviation is enough to cause discomfort. Living room (B) remained within comfort zone with an average temperate of 25.6°C.

The degree of acceptable indoor thermal comfort recorded in the bedroom and the Living room (B) is influenced by the courtyard which allowed for cross ventilation-a very integral factor in air flow, this made possible for fresh outdoor air to replace spent indoor air. The courtyard also provided for day lightning, thereby limiting the use of active lighting and cooling appliances, which heats up interior spaces.

The courtyard provided shading which prevented solar radiation from gaining entrance and heating up the interior, as in the case of Living room (A) whose windows opened to the West which made it gain heat from the sun.

Oral interview from the inmates of the flats revealed an acceptable level of indoor thermal comfort. This revelation goes to support the indoor thermal measurements carried out.

RECOMMENDATIONS AND CONCLUSION

The paper brought more realities to the use of courtyard in architecture. It in brief reviewed the use of courtyards in buildings history. It unveiled types, functions and benefits of courtyard in architecture, among which is energy benefit. Courtyards are extensively used for ventilation, thermal comfort and lighting and in the improvement of indoor air quality.

The paper recommended that architects be ahead in the race to employing the use of courtyards in their new schemes, especially as it provides safe outdoor environment, enclosed by the building. The paper concluded that, though courtyards in buildings is just one of the many passive design measures at architects' disposal but its benefits are far too many to be ignored. The paper is of the opinion that incorporating courtyards in architectural designs, will join other passive measures in enhancing the development of energy efficient buildings and in reaching a sustainable green environment.

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