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Evaluation Of Thermal Comfort In University Dormitories; A Case Study Of Suleiman Hall, Ahmadu Bello University Zaria, Nigeria.

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Abstract—The concept of user thermal comfort is very important in students' hostel. It affects the user's health, productivity and wellbeing, causing the user to not function to his/her optimum capacity. Much work has been done in addressing the individual factors of comfort especially in residential buildings. But little has been done in addressing the indoor thermal environment of hostels. Considering two or more factors of comfort. This research is aimed at examining user comfort in Suleiman hostel, A.B.U. Zaria. A survey of occupants of various types of rooms in the hostel was done to find out how they felt about their accommodation. A room was modeled in Autodesk Revit 2018 and was later simulated using Ecotect 2011. This led to the major finding that the ability of users to control the indoor environmental quality of their rooms is a strong variable in determining comfort in the dormitory. Also, it was found out that the indoor thermal environment of the dormitory was unsatisfactory. Based on the simulations carried out, the indoor thermal environment seems to be too hot during the hot season (summer) and relatively too cold during the harmattan season (winter). However, users are most interfered or interrupted by cleanliness, rowdiness and indoor air quality. This revealed that comfort is a subjective topic and as well, important for better health and productivity of occupants in the dormitory.

Index Terms—. Comfort, Thermal comfort, University dormitories, global warming

1 INTRODUCTION

Comfort is best defined as the absence of discomfort. People feel uncomfortable when they are too hot or too cold, or when the air is odorous and stale. Positive comfort conditions are those that do not distract by causing unpleasant sensations of temperature, drafts, humidity, or other aspects of the environment.

Thermal comfort is a state of mind that expresses satisfaction with the surrounding environment [1]. People in different climatic zones feel comfortable at different indoor air temperatures: a situation which can vary considerably from that of the world standards [2]. Thermal comfort in buildings could be achieved through both natural ventilation and mechanical methods. It is worrisome that most designers in the building industry have neglected the use of natural ventilation to achieve comfort in buildings instead, a lot of mechanical energy is used to generate the mechanical means of achieving ventilation in an enclosed space. [2].

A hostel is referred to a place where people can stay when their residence is located far from the educational institution and which is considered essential to students' needs, which also called student housing. Hostel is built with some institutional or formal characteristics and where students have access to the university recreational facilities. The influence of the environment and accommodation on the satisfaction level of university students is a popular study topic and is certainly of interest to the universities [3]. The chief goal of hostels is to provide quality living and sleeping environment for the occupants [4]. It is noted that a quality night sleep allows adequate daytime functioning: concentration, attention and comprehension as well as learning level. Similarly, also believed that thermal discomfort can affect the quality of sleeping environment and subsequently, the performances of daytime functions. Sleep is also an important factor that affect a person`s health and well-being. Health symptoms like fatigue, headache, stress and tiredness, undesired physiological stress on the body and aggressiveness are common scenario faced by occupants due to lack of quality sleep and bad thermal comfort conditions. Thermal comfort study in student hostels has not been fully explored using occupants comfort needs. This gap in literature motivated the researcher to conduct a field survey on indoor environmental conditions, occupants` thermal comfort and adaptation in a naturally ventilated hostel building.

Man has over the years been successful in creating environment that is conducive for all kinds of activities. One of the basic requirements for this environment is to maintain thermal conditions comfortable for occupants as this have a direct effect on health, productivity and morale [5].

As a problem statement for this research, Thermal discomfort results mostly from lack of adequate ventilation systems as a result of poor design considerations, climatic condition of the environment and global warming. Lack of adequate thermal comfort in university hostels leads to unsatisfactory thermal environment which in turn poses negative trends to students and in cases of outbreak of diseases endangers the health of the occupants.

Thermal comfort for human is one of the major problems at present. Providing thermal comfort for occupants in buildings is really a challenging task because it is not only influenced by temperature. The factors affecting thermal comfort depend on four environmental factors

- Air temperature
- Mean radiant temperature
- Relative humidity
- Air velocity

And two personal factors

- Clothing-insulation
- Metabolic rate.

Air Temperature is the temperature of the air surrounding the body. It is usually given in degrees Celsius [6].

The air temperature is measured using a thermometer with a dry bulb and is therefore called a dry bulb thermometer. A number of measures must be taken to ensure that the thermometer is not affected by other factors such as radiation [7].

Thermal radiation is the heat that radiates from a warm object. Radiant heat may be present if there are heat sources in an environment. Examples of radiant heat sources includes the sun, fire, electric fires, ovens, kiln walls, cookers, dryers etc [7].

Radiation is not measured at all meteorological stations but can be measured using a solarimeter which as the same implies, measures the strength of the main source of radiation; the sun. Inside buildings, we are more concerned with the relative balance of radiation from and to all surfaces visible from a given point. This can be measured using a globe thermometer which consists of a thermometer whose bulb is located at the center of a copper globe painted matt black so that the globe is highly sensitive to radiation [8].

Relative humidity is the ratio between the actual amount of water vapor in the air and maximum amount of water vapor that the air can hold at that air temperature.

Relative humidity between 40% and 70% does not have a major impact on thermal comfort. In work places which are not air conditioned, or where the weather conditions outdoors may influence the indoor thermal environment, relative humidity may be higher than 70%. Humidity in indoor environments can vary greatly and may be dependent on whether there are drying processes (paper mills, laundry etc.) where steam is given off. High humidity environments have a lot of vapor in the air, which prevents the evaporation of sweat from the skin. In hot environments, humidity is important because less sweat evaporates when humidity is high. The evaporation of sweat is the main method of heat reduction (Health and safety executives, 2016).

When non-breathable vapor-impermeable personal protective equipment (PPE) is worn, the humidity inside the garment increases as the wearer sweats because the sweat cannot evaporate. If an employee is wearing this type of PPE (e.g. asbestos or chemical protection suits etc.) the humidity within the PPE will be high (Health and safety executives, 2016).

The humidity of the air is measured in the Stevenson screen using a hygrograph, which records the relative humidity directly on a revolving drum, local measurements can be made using a wet and dry bulb hydrometer or a sling pyrometer [9].

Air velocity describes the speed of air moving across the employee and may help cool them if the air is cooler than the environment.

Air velocity is an important factor in thermal comfort for example:

- Still or stagnant air in indoor environments that are artificially heated may cause people to feel stuffy. It may also lead to a build-up in odor.
- Moving air in warm or humid conditions can increase heat loss through convection without any change in air temperature.
- Physical activity also increases air movement, so air velocity may be corrected to account for a person's level of physical activity.
- Small air movements in cool or cold environments may be perceived as a draught as people are particularly sensitive to these movements [10].

Air movement is measured in meteorological stations using a cup anemometer. Inside and around buildings where the lower wind speeds are not sufficient to give an accurate reading, a kata thermometer is used. This is a thermometer with only two indicators on the stem, the bulb is placed in hot water so that the mercury rises above the upper indicator. The time taken for the column of mercury to fall past the lower indicator is then measured and the speed of air passing the bulb can be estimated once the air temperature is known [11].

Thermal comfort is very much dependent on the insulating effect of clothing on the wearer. Wearing too much clothing or PPE may be a primary cause of heat stress even if the environment is not considered warm or hot. If clothing does not provide enough insulation, the wearer may be at risk from cold injuries such as frostbite or hypothermia in cold conditions. If clothing does not provide enough insulation, the wearer may be at risk from cold injuries such as frostbite or hypothermia in cold conditions [12].

The more physical work we do, the more heat we produce. The more heat we produce, the more heat needs to be lost so we don't overheat. The impact of metabolic rate on thermal comfort is critical.

A person's physical characteristics should always be borne in mind when considering their thermal comfort, as factors such as their size and weight, age, fitness level and sex can all have an impact on how they feel, even if other factors such as air temperature, humidity and air velocity are all constant [13]. One of the main objects of building design is to ensure the provision of continuous comfort for occupants in spite of adverse and variable external conditions. In terms of daylight, air quality, air movement and noise, the natural external conditions are surprisingly similar in all habitable climates and, for much of the activity. If these were the only variables, traditional building forms might well have been very similar throughout the world. Rainfall, humidity and thermal condition vary greatly with location on the earth's surface and it is particularly thermal conditions which has been the prime determinant of the traditional forms of buildings and modern buildings today for adequate indoor environment [13].

This research aims to assess the quality of indoor environment in a selected students' dormitory in Northern Nigeria.

2 REVIEW OF RELATED LITERATURE

The primary function of all buildings is to adapt to the prevailing climate and provide an internal and external environment that is comfortable and conducive to the occupants. However, in this era of climate change and global warming, providing comfort for the occupants of a building is quite challenging and very fundamental. This is as a result of growing ranges of challenges now facing designers to provide buildings that will be fit and comfortable for the 21st century [14].

Thermal comfort basically has to do with the temperature that the resident considers as comfortable to stay in. Indoor thermal comfort is achieved when occupants are able to pursue without any hindrance, activities for which the building is intended. Hence, it is essential for occupants' wellbeing, productivity and efficiency [15].

Man has over the years been successful in creating environment that is conducive for all kinds of activities. One of the basic requirements of this environment is to maintain thermal conditions comfortable for occupants as these have a direct effect on health, productivity and morale. What is more, ascertains that thermal comfort is attained when a thermal balance is achieved: a situation in which no heat storage occurs in the body. Although this can be achieved over a wide range of thermal environmental conditions, Thermal-comfort is associated with conditions to which the body can readily adjust. People in different climatic zones feel comfortable at different indoor air temperatures: a situation which can vary considerably from that of the world standards [16].

Poor air quality is a common problem in many urban and affects the health of people and environmental as well. Air quality improvement increases with increased present tree cover and decreased boundary layer heights. Urban vegetation and trees can directly and indirectly influence local and regional air quality by altering the atmosphere [17].Thermal and luminous environments influence user's comfort and building energy consumption [18]. Indoor air environments must be appropriate to the condition of thermal comfort and Indoor air quality. Thermal comfort is influenced by several factors, which principally contain air temperature, air humidity, air velocity, mean radiant temperature, human Clothing, and activity levels. Several specialists in this domain trust that indoor air quality may be the most important and relatively overlooked environmental issue of our time. Indoor pollutants leads to poor indoor air quality. The indoor environmental quality impacts not only health and comfort, but also the occupants, productivity, as it strongly affects working and learning competency, with effect on production and social costs. In particular, student Quarters are a type of buildings in which a high level of environmental quality may yield improved levels of individual concentration, learning, and performances. A lot of studies, in the last years, have been concentrated on finding relationship between the indoor environment and occupants performance and productivity in quarters building and working environments. Some of them are concentrated on the analysis of the various impact of the single aspects of the indoor air quality, such as acoustical, thermal, indoor air and visual quality on the overall quality estimation. Thermal comfort is a significant factor for the indoor air quality and it's also one of the main sources of energy consumption in quarters [19].

A hostel is referred to a place where people can stay when their residence is located far from the educational institution and which is considered essential to students' needs, which also called student housing. Hostel is built with some institutional or formal characteristics and where students have access to the university recreational facilities. The influence of the environment and accommodation on the satisfaction level of university students is a popular study topic and is certainly of interest to the universities [19]. Although the comfort zone is defined as a subjective assessment of the environmental conditions, the limits of the zone do have a physiological basis; the range of conditions under which the thermo-regulatory mechanisms of the body are in a state of minimal activity. Comfort, is dependent on several aspects and cannot be expressed in terms of any one of these aspects as they affect the body simultaneously and influence of any aspect depends on the levels of the other factors. Several attempts have been made to evaluate the combined effects of these factors on the physiological and sensory response of the body and to express any combination of them in terms of a single parameter or "thermal index" which can be set out on a monogram.

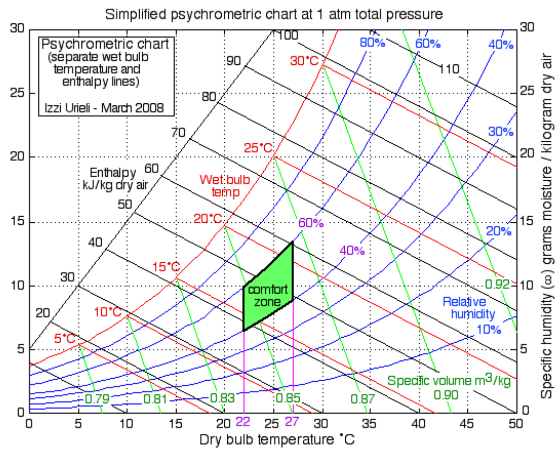


Figure1.1: Psychometric chart and the ASHRAE comfort zone

Source: [25]

When the fall of the quantity of solar radiation on the wall is part of that radiation is reflected back to the surrounding atmosphere, while absorbing the other part, which turns into energy increasing surface temperature of the outer wall first, and then the remainder joining to indoor air of the building. And take the heat and transferring it to the building in three forms which are radiation, conduction and convection [20].

Solar is gained from external sources and internally processed. Radiant heat refers to the heat that transfers through a vacuum through electromagnetic waves [21].

Heat convection refers to heat exchange between building and exterior air as well as with occupant, lights and equipment. The effect of internal sources of heat is minimized by having high internal inertia [22].

Heat conduction is the heat flow through material molecules from molecule has larger thermal energy to the molecule have least thermal energy. Nearly all of the heat exchange by conduction is between the building frame and the ground and this becomes appreciable in very cold climates [22].

[23] The thermal sensitivity of an individual is quantified by the descriptor which takes on higher values for individuals with lower tolerance to non-ideal thermal conditions. This group includes pregnant women, the disabled, as well as individuals whose age is below fourteen or above sixty, which is considered the adult range. Existing literature provides consistent evidence that sensitivity to hot and cold surfaces declines with age. There is also some evidence of a gradual reduction in the effectiveness of the body in thermoregulation after the age of sixty. This is mainly due to a more sluggish response of the counteraction mechanisms in the body that are used to maintain the core temperature of the body at ideal values. Situational factors include the health, psychological, sociological and vocational activities of the person [23].

While thermal comfort preferences between genders seems to be small, there are some differences. Studies have found men report discomfort due to rises in temperature much earlier than women. Men also estimate higher level s of their sensation of discomfort than women. One recent study tested men and women in the same cotton clothing, performing mental jobs while using a dial vote to report their thermal comfort to the changing temperature. Many times, females will prefer higher temperatures. But while females were more sensitive to temperatures, males tend to be more sensitive to relative humidity levels [23].

The type of climate and the concept of climatic design play the main role in building design strategies. In hot climates, as mentioned in different studies high heat gain during the summer and high heat loss during the winter period is the main issue, which affects the thermal comfort level of occupants. The Human body is faced with three common types of heat transfer methods and as their consequences during summer time body temperature will increase while in winter time it will be in reverse. Therefore, in order to provide comfortable situation for human in terms of temperature, an important concept introduced as Thermal Comfort. Thermal comfort is defined as the situation in which the body adopts itself to the environment by consuming the minimum amount of energy and its factors generally are divided into two major groups, objective and subjective. For instance, air temperature and relative humidity are objective factors, while thermal insulation, clothing and shape of the body are taken into account as the subjective factors Thus, in order to provide thermal comfort situation for those who live specially in hot regions, recognition of its problems and related solutions will be mandatory. In hot regions, buildings normally face three main issues with respect to the thermal comfort principles:

- Excessive heat gain in the hot weather
- Excessive heat loss in cold weather
- High relative humidity level

Therefore in order to reach an acceptable thermal comfort level, building as subject, should be designed in a way to reduce the above-mentioned defects. For instance, many studies have been performed on the properties of building envelope, building layout and orientation of building in order to eliminate the negative effects of hot climates on occupants' thermal comfort. These researches mention that building has to be designed appropriately by taking some major factors into consideration. These factors include, but are not limited to orientation, layout, form and materials. On the other hand, in a building that takes advantage of air conditioning system, in order to have efficient use of energy resources, the building has to be able to conserve energy generated in the field with use of sufficient insulation material [24].

Passive ways of achieving thermal comfort is the most viable option because of the epileptic power supply and high cost of air conditioning systems. These passive ways are:

- Proper Orientation of Building
- Proper Ventilation
- Using Shading Devices
- Proper Lighting
- Creation of Microclimate
- Preventing Infiltration
- Use of Light Color Paints
- Proper use of Electric Appliances
- Sensitizing Building Professionals [15]

3 METHODOLOGY

With the aim of accomplishing the set objectives of the research, literature relevant from the internet, textbooks, journals and thesis (published and unpublished) were taken into consideration. A single room in the dormitory will be examined with the sole purpose of gathering information on the subject matter. This is carried out in Kaduna State, Nigeria. A dormitory located in Ahmadu Bello University Zaria was remodeled in Autodesk Revit 2016 and later simulated. The research approach employed in this research was Quantitative using physical observations and real life measurements. The degree to which trees affect indoor air temperature in offices were tested using simulation software "Ecotect", a simulation software and the collection of the necessary data to assess thermal comfort quality in the structure. The results will reveal if the users of the building are comfortable with the indoor thermal environment or not. In this Research, Ecotect is used to analyze thermal comfort levels in Suleiman hall A.B.U. Zaria.

Hardcopies of the floor plans for the case studies were gotten from students who had previously used these buildings as case studies in their research. The floor plans were then redrawn using AutoCAD and modelled into a 3D form using Autodesk Revit Architecture 2016. The Zaria weather data file also was obtained. The floor plans were analyzed with the aid of Ecotect and other related softwares and the results are fully captured below. Interesting findings were made from the analysis of the data.

3.1 BUILDING DESCRIPTION

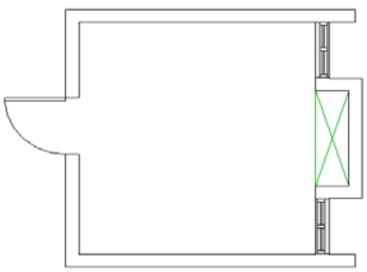
The dormitory is made of reinforced concrete frame with concrete floor and part roof, Sand/ cement block work to exterior and interior walls. The ground floor is raised above grade. There are cantilevered concrete walk ways and concrete railings along walk ways. The roofing was done using concrete deck. There are Vertical concrete louvers by the sides of the building. Exterior and interior walls painted using sand/cement render. The windows are Casement glazed steel windows. Doors are flush doors made of steel. The exterior of the building is painted off white to walls, light blue to wall base and gray to the window and door frames while the interior was painted dark gray to window frames, off white to Celotex ceiling, light green to door frames and crème to the walls. The elements regulating the amount of sunlight getting into the building are; the covered cantilevered walk ways and the recessed windows. Corrugated roof fall to concrete gutter discharging water to drain at the ground. All facilities are working and in a fairly good condition.

Umar Suleiman hostel is a hostel located in Ahmadu Bello University, Zaria. Zaria possesses a tropical continental climate with a pronounced dry season of up to seven months (October-May). During the dry season, a cool period is usually experienced between November and February. This emanates from the influence of the north-easterly winds (the harmattan) which controls the tropical continental air mass coming from the Sahara. This weather prevails over most parts of the country. The NE winds are characterized by hazy to dusty conditions and low temperatures as low as 10 degrees Celsius at night and up to 42 degrees is sometimes recorded during the day time. The humidity drops to less than 15% in December/January [24].

Zaria experiences a brief period of hot but dry weather in March and April followed by a progressive incursion of tropical maritime air mass from the Atlantic Ocean which displaces the NE (harmattan). During this short period, the mean daily maximum temperatures are fairly stable and they range from 38-42 degrees Celsius. After that, the south-westerly monsoon winds laden with moisture bring the rain in thunderstorms and squalls with heavy fall of high intensities. The rainy season lasts from May to October with long term annual rainfall of 1040mm in about ninety raining days [24].

Figure 1.2: A picture showing the approach view of a block in the dormitory
source; [24]

Figure 1.3: A picture showing the rear view of a block in the dormitory
source; [24]



3.2 RESULTS AND DISCUSSIONS

From the simulations conducted,.This is shown in figure 4.1. Using mixed-mode system, the indoor temperature maintained a value of 27⁰c from 8am to 9pm, which is the upper thermal comfort band for Zaria. This is shown in figure 4.2 below

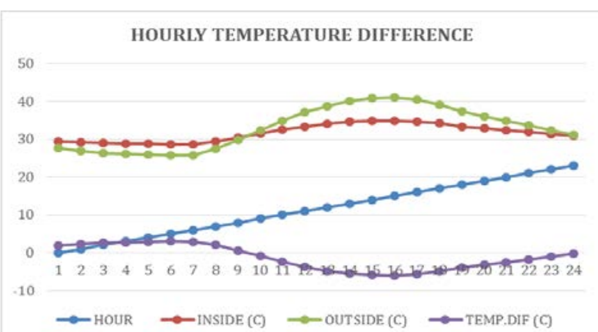


Figure 1.5: Hottest day peak temperatures using natural ventilation. Source: Ecotect, 2011

Figure 1.5 shows the temperature of the room using natural ventilation on the hottest day of the year. The indoor temperature for the hottest day peak (Saturday 7 March) using natural ventilation exceeds the upper thermal comfort band for Zaria with a peak value of 360c from 2pm to 7pm thereby making the indoor environment very uncomfortable for the occupants

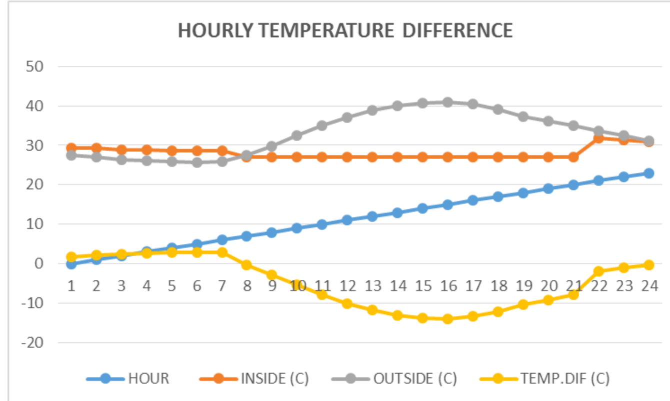


Figure 1.6: Hottest day peak temperatures using mixed mode of ventilation. Source; Ecotect, 2011

This is shown in figure below. Using mixed-mode system, the indoor temperature maintained a value of 36⁰c from 11am to 6pm, which is shown in figure 4.4 below. This also exceeds the upper thermal comfort band for Zaria.

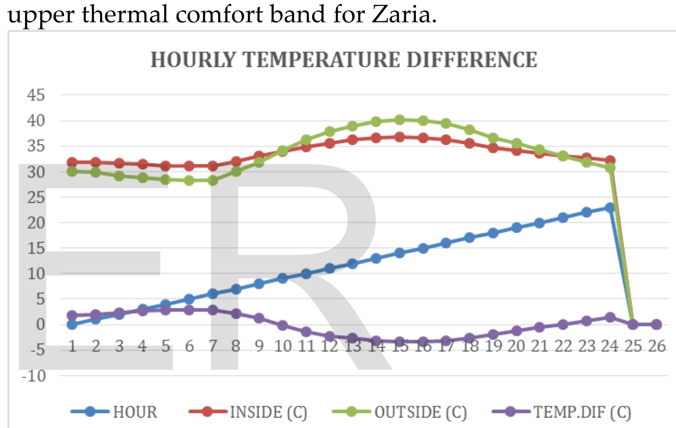


Figure 1.7: Average hottest day temperatures using natural ventilation. Source: Ecotect, 2011

From the simulations conducted, figure 1.7 shows the indoor temperature for the hottest day average (Wednesday 11 April) using natural ventilation exceeds the upper thermal comfort band for Zaria with a peak value of 36⁰c from 12pm to 7pm.

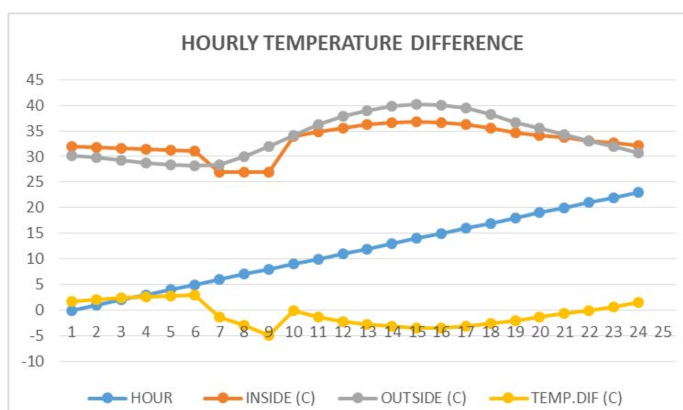


Figure 1.8: Average hottest day temperatures using mixed mode of

ventilation. Source: Ecotect, 2011

Figure 1.8 shows the average hottest day temperatures using mixed-mode system, the indoor temperature maintained a value of 36^{0}c from 11am to 6pm, which is shown in figure 4.4 below. This also exceeds the upper thermal comfort band for Zaria.

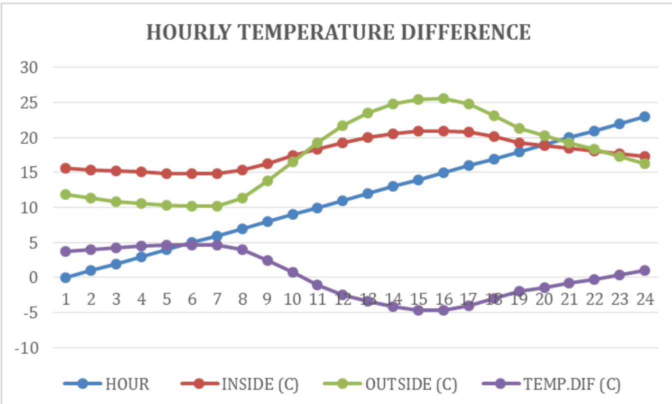


Figure 1.9: Coldest day peak temperatures using natural ventilation. Source: Ecotect, 2011

From the simulations conducted, figure 1.9 shows the indoor temperature for the coldest day peak (Saturday 13 January) using natural ventilation falls below thermal comfort band for Zaria with a peak value of 21^{0}c from 1pm to 6pm.

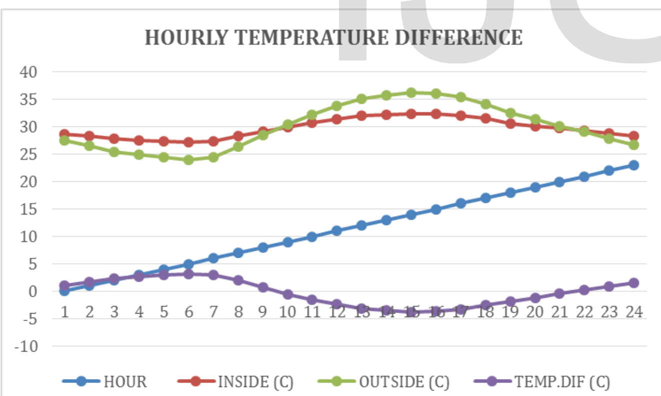


Figure 1.10: Temperatures for the day with the strongest wind gust using natural ventilation. Source: Ecotect, 2011

Figure 1.10 shows the indoor temperature for the day with the strongest wind gust (Saturday 30 June) using natural ventilation. The temperature exceeds the thermal comfort band for Zaria with a value of 28^{0}c from 1pm to 5pm.

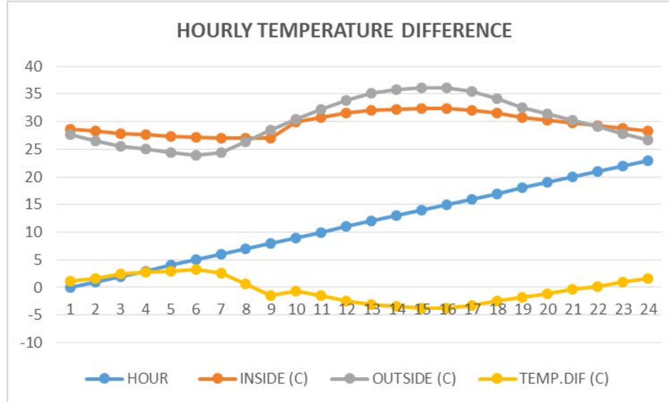


Figure 1.11 Temperatures for the day with the strongest wind gust using mixed mode of ventilation. Source: Ecotect, 2011

From figure 1.11 above, using mixed-mode system, the indoor temperature maintained a value of 27^{0}c from 11pm to 8pm which is the upper thermal comfort band for Zaria

4 CONCLUSION

In conclusion, this research highlighted the importance of thermal comfort to the satisfaction of the occupants of the. Factors responsible for thermal comfort in a building must be initiated in initial stages of the design process. From the results obtained from the simulation, it is clear to see that the thermal comfort level of the dormitory is on an unsatisfactory level all year round. The indoor environment is relatively too cold during the harmattan season (winter) and too hot during the hot season (summer). However to achieve optimum comfort, consideration such as the integration of shading devices should be considered, the orientation of the building, type of building materials to be used should be done as early as possible. A double skin façade can also be incorporated to the design of dormitories. Most of the time, a double-skin facade will provide thermal comfort during the winter. For the remaining time, a double-skin facade contributes to the heating of a building. In summer, the benefit of the system is limited because wind effects overcome the buoyancy effects on the south cavity except when the wind flows from the north (Alibaba & Ozdeniz, 2011). In order to produce a sustainable design then the architects or designer should put this into consideration. From findings, it is seen that comfort in the students' dormitories is important for better work and productivity. There are factors that interfere with study and wellbeing of occupants when accommodations are not comfortable for users; the result is low productivity and more frequent complaints, late coming to classes, tardiness in carrying out tasks and absenteeism from class, it may even result to outbreak of diseases. Architects play an important role in making sure hostels are comfortable for users. The extent to how comfortable a dormitory is can be determined by the Architect by considering those factors that cause discomfort in the hostel. If dormitories are designed to provide good indoor air quality and satisfy thermal comfort, then to a large extent, they become comfortable for the occupants thereby enabling them carry out their activities comfortably and in good health.

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