BOLGATANGA POLYTECHNIC

ASSESSMENT OF THERMAL COMFORT OF THE "NUBIAN VAULT" BUILDING WITH THE SANDCRETE BUILDING.

(A CASE STUDY IN BOLGATANGA MUNICIPALITY)

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BY

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JULY, 2018

DECLARATION

Candidates' declaration

We hereby declare that this project work is the result of our own original research and that no part of it has been presented for another Higher National Diploma in this Polytechnic or elsewhere.

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Supervisor's declaration

I hereby declare that preparation and presentation of the dissertation was supervised in accordance with the guidelines on the supervision of dissertation laid down by the Bolgatanga Polytechnic.

Name of supervisor	Signature	Date
Dr. Edward Naabil	.....	.....

ABSTRACT

Buildings are great assets to individuals and the nation. They are also regarded as an economic asset, which must be preserved to high value. Physical infrastructure constitutes a high proportion of the country's investment. It is therefore of primary importance that these facilities which include domestic buildings are kept in order that they can serve both the architectural and aesthetical functions for which they are built. The aim of the study was to conduct the assessment of thermal comfort of the 'Nubian vault' building to sandcrete building in the Bolgatanga Municipality.

Temperatures and humidity were taken from the various buildings in order to know the one with a good thermal comfort, which can be recommended to the people of the Bolgatanga Municipality.

The data collected were collated and analyzed using quantitative statistical tools such as line chart to display the results of the findings. Finding of the assessment of thermal comfort of the Nubian vault building to the sandcrete building is that, the Nubian vault building have a good thermal comfort as compared to that of the sandcrete building. The study therefore concluded by recommending that the people of the municipality should try to use the Nubian vault building since it has good thermal comfort to that of the sandcrete building.

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We are thankful to the staff of all the companies for thein valuable assistance during the period of data collection. We are grateful to our families and friends for their moral support and encouragement during the study.

May the almighty God richly bless you all for your support given to us throughout this study.

DEDICATION

We wish to dedicate this work to our parents for their undying love, support and for always being there for us.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

1.0 Background of the Study

According to Bahadoori (1998), thermal behavior of a building is determined by the extent of thermal controls provided in the building and the existing outdoor conditions. Man is an organism with great adaptive capacity. He is able to live under special environmental conditions that determine his quality of life. If he is to realize his full potential to live, he must respond to changes in the environment through thermo-regulatory mechanisms (Dobzhansky, 2000). He therefore requires an environment that is within the range of his adaptive capacity. When the climate fluctuates outside the norm, a reaction is required beyond his adaptive capacity and illness may develop. Buildings are used to provide shelter for man and maintain the environmental condition that determines the quality of life required for his existence.

Buildings are used to provide the microclimate required for human existence. It defines spaces for all human activities. As observed by Olanipekun (2002), buildings are essential modifiers of the microclimate; a space isolated from environmental temperature and humidity fluctuations, sheltered from prevailing winds and precipitation, and with enhancement of natural light. It has also been observed that effect of extreme climatic condition, which is discomfort, could be reduced by provision of environmental services Luff, (1984).

1.1 Problem Statement

Due to the consistent increase of the average global air temperature near the Earth' surface, - causing mild winters and hot summers, buildings will require less heating. Depending on the scenario, the number of heating degree-days around 2050 will decrease between 9 and 20% Hurk et al., (2006b). Van Dongen and Vos (2007) found in their study of 1240 Dutch homes that the

average indoor temperature is likely to be higher as houses are of a more recent date, mainly caused by less temperature decrease at night. Relatively warm night temperature can cause problems for the night's rest. A small (short term) skin temperature change of less than 1°C has already a large impact on sleep quality, especially for the elderly Raymann et al., (2008). Long-term changes in environmental temperature can result in an adjustment of the basal metabolic rate and heat production by altering hormone secretion Kapit et al., (2000).

Therefore, air conditioner use will increase during hot summers. This will affect the power use significantly. The effects of electricity shortfall for during hot days in (rich) countries with warmer climates like the US, Canada and Ghana in particular are already noticeable. Meier,(2006) found that a shortfall electricity in Arizona was mostly driven by air conditioning, but an electricity shortage in Norway was caused by drought, in the case of Ghana, an electricity shortfall is cause by air condition usage due to high air temperature and also due to shortfall in the shortfall in the hydro dams. The causes of the shortages include many severe weather events, such as droughts, heat or cold waves. Intentional cut-backs in electricity consumption without fully understand all consequences, will not automatically lead to less problems and more energy efficiency

1.2 Aim of the Study

The main aim of this study is to assess the thermal comfort of the "Nubian Vault "building with the sandcrete building.

1.3 Objectives of the Study

The specific objectives of this research are as follows:

1. To assess the effects of the thermal comfort of the "Nubian Vault" building with the sandcrete building.

2. To identify control tools that can be used to enhance the "Nubian Vault" building with the sandcrete building.
3. To determine the comfort ability of either building.

1.4 Research Questions

The research questions of this study will be as follows:

1. What are the effects of the thermal comfort of the "Nubian Vault" building with the sandcrete building?
2. What are the control tools that can be used to enhance the "Nubian Vault" building with the sandcrete building?
3. How can the comfort ability of either building be improved?

1.5 Organization of Chapters

This project work is organized into five (5) chapters. Each chapter has a number of sections and sub-sections.

- CHAPTER ONE dealt with the introduction which entails the background to the study, the objectives and relevance of the research, the research questions, the limitations and delimitations. More importantly, the chapter introduces the problem statement, the justification of the study.
- CHAPTER TWO entails, Review of relevant literature; provides a review of selected articles, books peer report of the subject area of research. It will collate ideas, opinions, views and positions of past studies that related to the contextual subject of the study. The review is then used to formulate a conceptual framework to the project.
- CHAPTER THREE offers the methodology, specifically, the study type, tools and procedures used to collect data needed to address the research problems.

- CHAPTER FOUR is dedicated to the analysis of data and discussion of the research findings and finally,
- CHAPTER FIVE provides summaries of important issues discussed in the project and attempts to reach a relevant conclusion from all of the work undertaken. Recommendations are also provided.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter presents an extensive and thorough review of relevant publications and studies related to the research problem under investigation in order to obtain detailed knowledge about the area under study.

2.1 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 Amos-Abanyie, (2012). When thermal mass is exposed to the interior, it absorbs heat from internal sources and dampens the amplitude of the indoor temperature swing Chenvidyakarn, (2007). 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 Yam et al., (2003).

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. Szokolay, (2004) accounts that absorptance/ reflectance will strongly influence the solar heat input. Reardon, (2010) agrees with Szokolay, (2004) 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.

Apart from high thermal mass, other strategies such as night ventilation and natural ventilation are known to reduce indoor temperature and the energy use in buildings around the world. For

instance, Pfafferott et al., (2003) confirmed that night ventilation reduced the mean room temperature by 1.2°C during the daytime for a building in Freiburg/Germany and so did Geros et al., (1999) who also found the average reduction of the temperature in a building in Greece to be between 1.8 and 3°C after using night ventilation. Natural ventilation on the other hand can reach much higher ventilation rates than mechanical ventilation systems, which are especially designed for fresh air supply Aggerholm, (2002).

2.2 Orientation

The orientation of a building is a contributing factor on how much energy it would use to provide thermal comfort for its occupants.

Seok-Hyun et al., (2013) declare that the amount of sunshine that enters an interior space is affected by the orientation of a building. The designer of a window should consider the orientation of the window to be installed. On a normal summer day, the amount of sunshine at the east and west is small but the west requires a larger cooling load in the afternoon because of the afternoon sunshine. The south has a larger amount of sunshine but the solar radiation can be blocked easily by shading. Salmon, (1999) establishes the fact that "buildings should be able to respond to changes in climate by the rejection of solar heat and have the thermal integrity to maintain internal comfort, despite the influence of climatic forces acting on the building envelope. In addition, the building should be able to retain cool conditions, in order to maintain comfort. In this regard, the exact solar orientation is not critical." Salmon, (1999) however, establishes that analyses of sun paths and wind directions have shown that elongated buildings should be oriented to the south. In addition, the best orientation for wind is the southwest whilst a compromise of 22.5° (south-southwest) should give the best orientation. Contrary to Salmon view, Lauber (2005), recommendation was that the best orientation for buildings in the warm and

humid countries should be +/-30° from the prevailing wind direction. He further states that the shell of air-conditioned buildings must be insulated, windproof and airtight. This suggests an orientation away from the prevailing wind direction, but there is no precise direction for air-conditioned buildings Lauber, (2005).

Szokolay (2004) also had a different proposal from the above mentioned authors. He suggeste that in order to ensure maximum cross ventilation in a building, the major openings should face within 45° of the prevailing winds. All the above suggestions from these authors are for naturally ventilated buildings.

2.3 Thermal Performance of Buildings

Thermal performance and efficiency of buildings should be measured through climate responsive design. The use of site and climate for design with regard to thermal efficiency has further potential for reducing active energy which is the operational energy of the building. Due to increased concern for passive energy utilization for provision of thermal comfort, opinions have been developed to assist with saving of the energy through life cycle costing. This fundamentally involves the computation of the capital cost of the building and cost of operating the building over its projected life Lawal, (2008).

The active energy cost often exceeds the capital costs of buildings. Climate conscious design requires a thorough understanding of the local climate; and the employment of several strategies for the creation of an agreeable micro-climate with maximum thermal comfort of the indoor spaces.

According to Madueke andOpoko, (1998), structural control of a modern buildings are its main parts such as walls, roof, floors and glazed materials (glass) in openings. The ability of a building enclosing elements to conduct heat from one side of the wall to the other is the thermal

transmittance denoted as U-value for the element. The U-value, according to Ezeilo, (1998), determined in the tropics, varies with the type of enclosing building elements. For the roof, it depends on materials used, thickness of materials and space, vapour barrier, temperature and surface texture, and ranges from 0.08-3.22 W/M2 0C. For glazed materials, it ranges from 2.2-8.74 W/M2 0C, while modern walls constructed of sandcrete block, which is a physical mixture of sand, cement and water in varying proportions, has a U-value 0.75-6. 53W/M2 0C (BRE, 1988) depending on the materials used, insulating materials and others.

The Nubian Vault is one of the old building technologies that are being recovered and diffused in different countries. The Nubian Vault Association standardized this ancient technique and is teaching it to communities in Burkina Faso, Mali, Senegal and Ghana, where deforestation has led to scarcity of timber and straw for traditional roof construction. The Nubian Vault construction technique uses local skills and labour and renewable materials (earth, rocks, water) for sustainable low cost homes and other buildings. They are environmentally friendly and cheaper, more comfortable and longer lasting than the widespread, but expensive cement blocks and metal roofed buildings.

This technique comes from Nubia, in Egypt, where it has been used since ages and it was revived and disseminated by the Egyptian architect Hassan Fathy, in the framework of a worldwide renaissance, in the 20th century, of earthen architecture and construction with arches, vaults and domes. The Nubian Vault technique was experimented in Burkina Faso by the Burkinabé builder SériYoulou and the French builder Thomas Granier, in order to adapt the construction building process to local conditions Ben Hobson, (2016). In particular the prototypes were constructed entirely from earth bricks and earth mortar, without using any timber either for shuttering or in the structure of the buildings.

In 2000 the Association la VoûteNubienne (AVN) was formally established as a technical support for the Earth roofs in the Sahel Programme realized by UN Habitat and the Ashoka foundationPatrick Sisson,(2017).Despite the fact that the Earth always had a changing climate throughout its 4.5 billion years of history, today's climate changes seem different than before (e.g., Holmes & Hacker, 2007). Preceding evidence shows that humanity plays an important role with respect to climate change, as concluded by the Intergovernmental Panel on Climate Change [IPCC] (IPCC, 2007) in the Fourth IPCC Assessment Report 'Climate Change 2007'. Since the first measurements of CO2 in 1958 by Revelle Gore, (2006), scientists have warned us about climate change and possible consequences. The problem is named 'radiative forcing', which is defined as the change in average net radiation at the top of the troposphere (lower atmosphere). Positive radiative forcing warms up the Earth' surface to keep the heat balance. Negative radiative forcing would cool down the surface of the earth Houghton, (S2004). In scientific literature, a debate and controversy exists about the actual cause of radiative forcing; in particular about the relative importance of anthropogenic or human induced sources versus natural influences such as the variability of the solar activity and radiation. Although it seems that something is happening with our climate, what exactly will happen in the next centuries is difficult to predict.

2.3.1 The Nubian Vault

The Nubian Vault is one of the old building technologies that are being recovered and diffused in different countries. The Nubian Vault construction technique uses local skills and labour and renewable materials (earth, rocks, water) for sustainable low cost homes and other buildings. They are environmentally friendly and cheaper, more comfortable and longer lasting than the widespread, but expensive cement blocks and metal roofed buildings.

The Nubian Vault is a novel reinterpretation of an ancestral technique, revived by AVN in order to allow access to appropriate and affordable housing to as many people as possible, as soon as possible. AVN bases its action on key technical innovations, adapted to the Sahelian climate, resources and social and economical context.

The Nubian Vault technique is an age-old method of timber-less vault construction, Originating in Upper Egypt. It uses only earth bricks and earth mortar.

During the last fifteen years, AVN has successfully introduced a simplified, standardized version of this ancient technique in Burkina Faso, Mali, Senegal, Benin and Ghana.

2.3.2 Sandcrete Building

According U.S Agency for international development, (1963), Sandcrete is a yellow-white building material made from a binder (typically Portland cement), sand in a ratio of circa 1:8, and water. Sometimes other ingredients may be added to reduce the amount of expensive Portland cement such as pozzolanas and rice husk ash. Sandcrete is similar but weaker than mortar, for which the ratio is circa 1:5. Soil cement and landcrete are similar materials but use other types of soil.

Sandcrete is usually used as hollow rectangular blocks similar to concrete masonry units, often 45 centimeters (18 in) wide, 15 centimeters (5.9 in) thick and 30 centimeters (12 in) with hollows that run from top to bottom and occupy around one third of the volume of the block. The blocks are joined together with mortar.

Sandcrete is unsuitable for load-bearing columns, and is mainly used for walls, or for foundations if no suitable alternative is available. As material for walls, its strength is less than that of fired clay bricks, but sandcrete is considerably cheaper.

Sandcrete is the main building material for walls of single-storey buildings (such as houses and schools) in countries such as Ghana and Nigeria.

2.4 Comfortability

The most obvious requirement of any dwelling is to enable people to rest, eat and sleep comfortably (Angus, 1968; Appah&Koranteng, 2012). A good indoor climate is the one which takes individual needs into account, facilitates personal influence on environmental conditions and particularly considers the needs of sensitive and exposed groups. It also ensures absence of damaging effects on health and ensures that at least, 80% of residents or users of buildings are satisfied (Fergus et al, 2012; Torben& Peter, 2010). This is perhaps the most important aspect of the design since if the occupiers are not satisfied with the comfort conditions within; the building is regarded as a failure. Human considers an environment as thermally comfortable if no thermal discomfort is present, else they either feels too warm or too cold. Their perception of indoor (i.e. interior) thermal comfort is largely influenced by the fabric of the building and its envelope (particularly the floor, wall, window and roof) as well as his current thermodynamic processes at the time of comfort evaluation (Ward, 2004).

2.4.1 Comparing the thermal comfortability of Nubian Vault to Sandcrete building

To facilitate comfortable interior living conditions in this region on one part, direct application of technological advancement of Nubian Vault should be enhanced, because with the Nubian Vault they will be no need for air-conditions to cool the room in case of roof absorbing and transmitting heat into the room. With the sandcrete building, integration of active energy source into the building design for attainment of thermal comfort by the users is required, because mostly during the day time we learned that the building absorbs heat and intend distribute it to the interior of the building, without air-conditions to sack away the heat, the room will be too

uncomfortable. However, this is achieved not without the attendant use of non-renewable fossil fuelling source(s) which is usually characterised with its resulting phenomenal global warming, atmospheric pollution, dwindling natural resources, and disruptions in eco-systems, among others. (Koenigsberger et al, 1974; Baofeng, 2004 ; Michael & Friedrich, 2002; Hyde, 2000).

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

This chapter presents the research methodology of the study. It describes and justifies the methods and processes used to collect data that will help achieve the research objectives. The chapter is presented under the following sections namely: introduction of research methodology, research design, data collection. The aim of the research is to assess the thermal comfort of the "Nubian Vault" building with the sandcrete building and to achieve this, the researchers will carry out an in-depth evaluation of the design process with the intention of identifying instances in which thermal comfort can occur. This will be done through a review of the available literature on the thermal comfort of the "Nubian Vault" building with the sandcrete building, causes of thermal comfort of the "Nubian Vault" building with the sandcrete building, effects of thermal comfort of the "Nubian Vault" building with the sandcrete building and ways used to mitigate the effects.The research methodology will involve primary and secondary data collection (temperature and humidity from the Nubian vault and sandcrete building).

Primary data will involve the use of hobo mobile to collect the data. Secondary information will involve literature review of journals, books and other relevant publications. Data analysis will be done usingMS Excel office application and graphs.

3.1 Research Design

Kothari (2003) defines research as the pursuit of truth with the help of study, observation, comparison and experiment, which is a systematic method of finding solutions to a research problem identified. Research methods may be understood as all those methods/techniques that is used for the conducting of research.

Research methodology on the other hand is inclusive of the research methods and encompasses the overall approach to the research process from definition to selection of the appropriate research method and analysis of data and drawing conclusions from the analysis.

Kothari (2009) explained it as a way to systematically solve the research problem.

There are two basic approaches to research; quantitative approach and the qualitative approach (Kothari, 2009). Qualitative Research is collecting, analyzing, and interpreting data by observing what people do and say (Anderson, 2006) whereas quantitative research is an inquiry into an identified problem, based on testing a theory composed of variables, measured with numbers, and analyzed using statistical techniques. It deals with numbers and their manipulation in order to gain insight in that which is being studied. This study adopts both quantitative and qualitative research approach to achieve the objectives of this research.

3.2 Description of the Study Area .

Study population is defined as the aggregate of all study unit, they have a potential for providing relevant data for the study. A particular population has some characteristics that differentiate it from other population. The research target is at Bolgatanga Municipality. The study area was preferred because construction activities involving consultants and contractors take place in Bolgatanga. Besides, most of the consultants in the study will be concentrated in the area. The study area was also chosen because of its proximity to the researchers, and also due to constrain of time and money. It is however assured that the findings from the research will give an overview of the entire construction industry all over the country.

Mugenda (1999) refers to population as an entire group of individuals, events or objects having the common observable characteristics to which the research wants to generalize the result of the study. The target population under study is the professional practicing firms in the construction

industry in Ghana. They include contractors and consulting quantity surveying, architectural and engineering firms together with the developers who are involved in the projects. The accessible population includes developers/clients, contractors and the consultant team of projects. The study, however will consider large construction projects, which will result up to a population of 50 projects because some of the developers, contractors and consultants have more than one project.

3.3 Data Collection

The type of data that will be used for the study is primary. This is the first hand data that will be collected directly from the field. The study primarily will use first hand data collected directly from field. The study made use of an instrument called HOBO data logger. The HOBO data logger was used for measuring temperature and relative humidity. These sensor were placed in the respective building (Nubian vault and sandcrete building) for four weeks (March 1 to 31, 2018). Secondary data will also be used as reference material sourced from past research studies, textbooks, journals and articles.

3.3.1 Method of Data Collection

A detailed field survey of the study area was conducted in February 2018 to investigate some data: height, layout, material and so on. Again temperature and relative humidity were measured by using HOBO logger in the study area (Nubian vault and sandcrete building) in March 1st to March 31st, 2018. The data was recorded from 12:10am to 11:59pm.

3.3.2 Instruments of Data Collection

The instrument of data collection that will be used in the study will be HOBO logger.

CHAPTERFOUR

RESULTS ANALYSIS AND DISCUSSION

4.0 Introduction

Thissectionpresentsthe summary of results analysis and discussion of the study. The results were obtained based on data recording if temperature and relative humidity of the Nubian Vault and sandcrete building. This was established to determine the weather condition in the Nubian vault and sandcrete building.

4.1 Thermal Comfort and Human Performance

Human beings partake in various activities within building enclosures. These activities can only be performed best when the environmental conditions are favorable. Inside a building, people are affected either positively or negatively because of the physiological reactions and psychological responses to the thermal environment. Thermal comfort plays a significant role in human performance at both mental and physical levels. The level of performance of given tasks would indicate the level of influence generated by the impulses caused by the varied environmental parameters. To determine the thermal comfort of the "Nubian vault" building with the sand Crete building, an instrument called Hobo Mobile was used to take temperature and relative humidity of the Nubian vault and sandcrete building from 1st of March, 2018 to 30th of March, 2018.

4.2 Climate control

It is indicated in figure 1 that, temperature from Nubian vault building shows a low temperature producing rate with a low temperature of 29.43 degrees on day 2 as compared to the sandcret building with a temperature of 34.50 degrees. Again, the Nubian vault building shown a low humility on day 26 to day 28 with degrees of 19.57, 18.35 and 16.94 respectively as compared to the sandcrete

building which shown a high humidity rate of 39.89, 39.43 and 38.87 respectively. Climate control refers to the control of temperature and humidity in buildings, vehicles and other enclosed spaces for the purpose of providing human comfort, health and safety and of meeting environmental requirements of machines sensitive materials (for example, historic) and technical process.

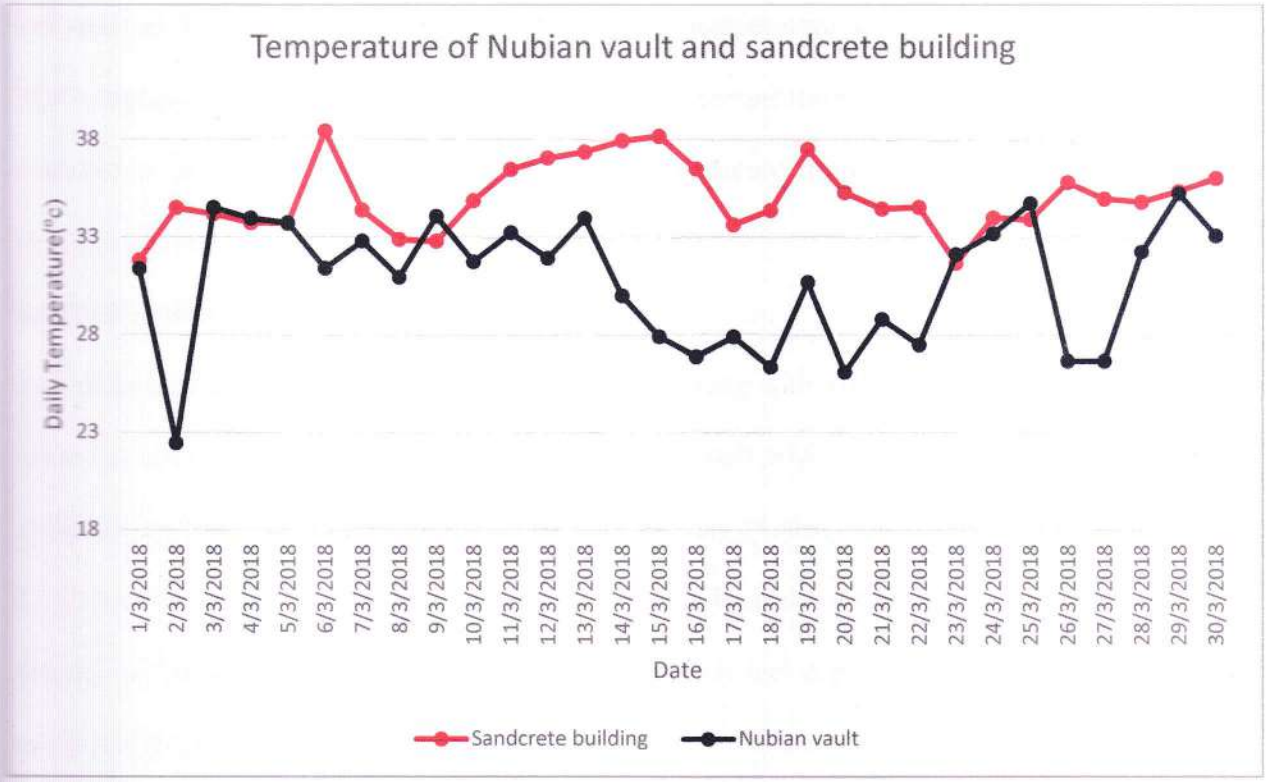

Fig. 1 Temperatures of the Nubian vault and the sandcrete building

From Figure 1 it is indicated that, the temperature in Nubian vault with a high temperature of 35.23°c and a low temperature of 26.09°c is conducive as compared to the temperature in the sandcrete building with a high temperature of 38.42°c and a low temperature of 31.64°c. This implies the Nubian vault will be advisable for the comfort of the people in the Bolgatanga municipal instead of sandcrete building. As it was confirmed by Szokolay, (2004) that 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.

4.3 Temperature from the Nubian vault building and the sandcrete building

It is revealed in figure 1 that, temperature from the sandcrete building rises from the first day with a temperature of 31.81 degrees to 34.38 degrees on the seventh day, as compared to temperature from the Nubian vault building which temperature starts from 31.37 degrees to 32.79 degrees on the seventh day. This implies that, temperature from sandcrete building will continue to increase as the days goes by, whiles temperature from the Nubian vault reduces as the days goes by.

4.4 Human discomfort caused by high temperature

It is indicated that, temperature from the sandcrete building with a degree of 36.47 on day 11 will cause human discomfort as compared to the Nubian vault with a temperature degree of 33.22. Temperature from the sandcrete building recorded on day 14 also indicates a high temperature of 37.93 as compared to temperature from the Nubian vault on day 14 with a temperature of 29.98 degree, which shows that, residuals (human beings) will feel comfortable in a Nubian vault as compared to the sandcrete building.

4.5 Relative humidity from the Nubian vault building and the sandcrete building

Relative humidity is the ratio of the partial pressure of water vapor to the equilibrium vapor pressure of water at a given temperature. Relative humidity depends on temperature and the pressure of the system of interest. It requires less water vapor to attain high relative humidity at low temperatures; more water vapor is required to attain high relative humidity in warm or hot air.

4.6 Human discomfort caused by high relative humidity

Humans are sensitive to high humidity because the human body uses evaporative cooling, enabled by perspiration, as the primary mechanism to rid itself of waste heat. Perspiration evaporates from the skin more slowly under humid conditions than under arid. Because humans perceive a low rate of heat transfer from the body to be equivalent to a higher air temperature, the body experiences greater distress of waste heat burden at high humidity than at lower humidity, given equal temperatures. For example, if the air temperature is 24 °C (75 °F) and the relative humidity is 0%, then the air temperature feels like 21 °C (69 °F). If the relative humidity is 100% at the same air temperature, then it feels like 27 °C (80 °F). In other words, if the air temperature is 24 °C (75 °F) and contains saturated water vapor, then the human body cools itself at the same rate as it would if it were 27 °C (80 °F) and at 20% relative humidity (an unstated baseline used in the heat index). The heat index and the humidex are indices that reflect the combined effect of temperature and humidity on the cooling effect of the atmosphere on the human body. It was confirmed by Seok-Hyun et al., (2013) that the amount of sunshine that enters an interior space is affected by the orientation of a building.

However, based on the above findings, the average relative humidity the occupants are exposed to in the sandcrete building is 8% to 50% and that of Nubian vault is 15% to 60% (figure 2). It was confirmed by Olesen B. W. and Brager G. S. (2004) that humidity has little or no effect on thermal comfort when within 60% to 90%.

This shows that, the Nubian vault present a normal humidity, that create a better thermal comfort than the sandcrete building.

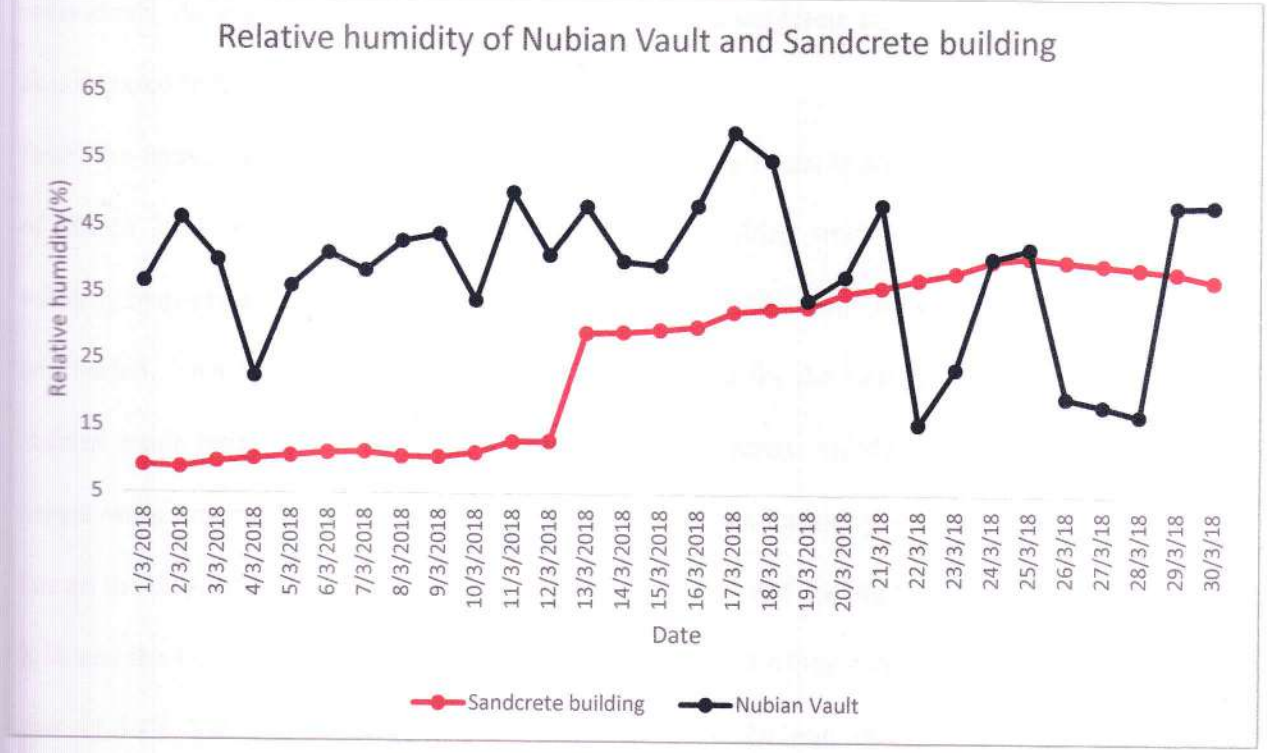

Figure 2: Relative humidity of Nubian vault and sandcrete building.

4.7 Human discomfort caused by low relative humidity

In figure 2, the sandcrete building indicate a relative humidity of 9.09% whereas the Nubian vault building indicates a relative humidity of 36.69% for the first day of the month. In this case the Nubian vault presents a normal humidity, thus creates a better thermal comfort than the sandcrete building.

Humans can be comfortable within a wide range of humidity's depending on the relative humidity—from 30% to 70%—but ideally between 50% and 60%. It is revealed in **figure 2**, the sandcrete building indicates a relative humidity of 9.09% whereas the Nubian vault indicates a relative humidity of 36.96% for the first day of the month. In this case the Nubian vault presents a normal relative humidity, thus creates a better thermal comfort than Sandcrete building. A very low humidity can create discomfort, respiratory problems, and aggravate allergies in some

individuals. As indicated in **figure 2**, humidity from the sandcrete building shows low humidity as compared to humidity from the Nubian vault.

From the above figure, the average relative humidity was taken from 1st of March, 2018 to 30th of March 2018 in which the data was taken for the Nubian vault building and the sandcrete building respectively, from the table it indicates that the relative humidity that was taken for each day varied, from the relative humidity that was recorded for the first day it was relied that the Nubian vault building recorded 9.09% whiles the sandcrete building recorded 36.69%. The values were not gotten by outburst or gust but the average humidity was taken for all the days. For all the days the lowest relative humidity that was recorded for the Nubian vault building was 8.78 and the highest relative humidity was 40.57% and that of the sandcrete building, the lowest was 15.56% and the highest was 59.13% Relating the Nubian vault building to that of the sandcrete building we will say based on the results gathered the sandcrete building will be hotter than that of the Nubian vault building.

The study shows that the relative humidity in the Nubian vault recording a high relative humidity of 59.13% and low relative humidity of 15.56% is conducive as compared to sandcrete building recording a high relative humidity of 40.57% and a low relative humidity of 8.78%. This implies the Nubian vault has a good relative humidity under the weather condition of the Bolgatanga municipal than the sandcrete building.

4.8 Advantages of Nubian Vault Building

1. It's very fast to construct
2. It's very cheap to construct
3. No need for only skilled personnel
4. It have high tensile strength

5. Can be used in high seismic zones
6. Nubian Vault buildings provide excellent thermal insulation, making the buildings cool during the day and warm during the night.
7. This architectural technique is widely supported by environmentalists as it only uses pure mud, thereby reducing the use of timber.
8. Another key advantage of the Nubian Vault technique is that it does not require the use of imported sheet metal for roofing or timber beams for support.
9. "Nubian Vault uses only locally available materials with a very low carbon footprint," says Nuttall.

Nubian Vault housing technology, an ancient Egyptian building technology has been introduced in the Upper East Region to help breach the housing gap in Ghana which stands at 1.7 million.

The technology which uses only local materials such as mud, clay and stone is expected to be adopted by the country to ease building challenges and also afford the poor the opportunity to own their own houses.

Being the first of its kind introduced into an English speaking African language, the technology has been introduced to parts of Africa including Senegal, Benin and Burkina Faso.

At a ceremony to commission the new National Office of the Nubian Vault Association in the Upper East Region, National Coordinator for Nubian Vault Association, Mr. GuilioCocchini said although the technology is an ancient Egyptian building technology, it has been adapted to suit the climatic conditions in various parts of Africa.

He noted that, building houses comes with various difficulties especially with the patronage of imported materials such as cement, iron rods and woods but was quick to add that the introduction of this technology will ease problems related to building.

He added that, the technology will create employment considering how cost effective the building is and the materials needed to build the house. He indicated that training of masons for the ancient building technology comes with no cost.

4.9 Sandcrete Building

Result from figure 2 reveal's that, the sandcrete building produces more temperature and humidity as compared to the Nubian vault. Results show a high temperature of 38.42 degrees on day 6 as compared to the Nubian vault which was 31.39 degrees. The Sandcrete Building is an age-old architectural technique originating in the world. This technique allows the construction, with materials such as sand, cement, stones, timber, iron, skilled personnel and among others in its construction. Its specificity is marked by the use of sand and water to make a mortar and blocks. In this type of construction, roofing sheets are needed to cover the top and also to form frameworks. This could be the reason for high temperature recorded in the sandcrete building.

4.10 Advantages of the Sandcrete Building

Some of the advantages of the sandcrete buildings are as follows

1. Compressive strength is good enough for ordinary construction
2. Very low maintenance cost is required
3. Reusable and recyclable
4. Hard and durable
5. Highly fire resistance

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.0 Introduction

This chapter presents summary of the findings of the study, the conclusions made from the findings and recommendations.

5.1 Summary

The analysis first reviewed the general thermal comfort of the Nubian Vault Building to the Sandcrete Building. An instrument used for measuring temperature was used to measure the temperatures of the Nubian vault building to that of the sandcrete building, also it was used to measure the `relative density of each of the building, results were discussed in the previous chapter. Results were put on tables and interpreted.

Human beings partake in various activities within building enclosures. These activities can only be performed best when the environmental conditions are favorable. Inside a building, people are affected either positively or negatively because of the physiological reactions and psychological responses to the thermal environment. Thermal comfort plays a significant role in human performance at both mental and physical levels. The level of performance of given tasks would indicate the level of influence generated by the impulses caused by the varied environmental parameters.

5.2 Conclusion

The purpose of the study presented was to determine the thermal comfort of a Nubian vault and sandcrete building and to identify which of these building system will be conducive for the people of the Bolgatanga municipality. Therefore, the temperature and relative humidity of the Nubian vault and sandcrete building were recorded by the researchers.

The study reveal that, the thermal comfort of the Nubian vault will be conducive for the people of the Bolgatanga municipality than the sandcrete building, so it will be advisable for the people to build the Nubian vault instead of the sandcrete building.

Construction and building projects are progressively reaching a point of complexity in terms of size and cost. In other industries the cost of a product is based on known manufacturing cost whereas in construction most projects must be priced before they are constructed making the industry distinct with risky operations. One important factor which plays a role when the performance of a construction is the cost of the construction, with construction money is needed for it, and the type of the building will determine the amount of money needed to construct it. Comparing the cost of constructing the Nubian vault building to the sandcrete building, the cost for constructing the sandcrete building is higher than that constructing the Nubian vault building. Comparing the thermal comfort of the Nubian vault building to that of the sandcrete building, it was realized that, the thermal comfort of the Nubian vault building was good as compared to the sandcrete building.

5.3 Recommendation

Based on our findings of this research discussed in chapter four with main conclusion listed above and referring to findings of previous studies discussed in the literature review, the following recommendations were made:

ecologically sustainable; no corrugated iron roofing sheets, nor timber beams, rafters, or supports, is also carbon neutral; none of the construction materials are manufactured, or transported long distances, nor do any trees need to be cut down, also, it is economically viable; only locally available raw materials (earth, rocks, and water) are used, favoring local economic circuits and self-sufficiency, it is also comfortable to leave inside due to the excellent thermal

and acoustic insulation properties of earth construction, durable is one of the importance, Nubian Vault buildings have a far longer lifetime than those with corrugated iron and timber roofs, and maintenance is simple, it is also modular; applicable to a wide range of buildings (houses, schools, health centers), of different styles (flat terrace roofs, two-stories buildings, courtyard buildings), which are easily extendable and vernacular: incorporating traditional practices and aesthetics of earth architecture. Asconcludedearlier,theresearchindicatesthat, the thermal comfort of the Nubian vault building is good as compared to that of the sandcrete building. The Nubian vault will play a vital role in terms of the building economic cost than the sandcrete building for the people of the Bolgatanga municipality.

If the Nubian vault system of building is practice, it will play vital roles in terms of thermal comfort and economic cost of buildings in Ghana and beyond.

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