

A STUDY OF RAMMED EARTH AS A SUBSTITUTE FOR CONCRETE AND SANCRETE
IN CONSTRUCTION IN EDO STATE.

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SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE, FACULTY OF
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PARTIAL
FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF
SCIENCE (B.Sc.) DEGREE IN ARCHITECTURE

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DECLARATION

I hereby declare that this project titled “A STUDY OF RAMMED EARTH AS A SUBSTITUTE FOR CONCRETE AND SANCRETE IN BUILDING CONSTRUCTION” has been carried out by me in the Department of Architecture, Faculty of Environmental Sciences, University of Benin, Edo State, Nigeria. The information derived from literature has been duly acknowledged in the text and a list of references provided. No part of this text was previously presented for another degree in this university or in any other institution.

All materials consulted in the course of this research are duly acknowledge in a list of references provided.

NAME OF STUDENT

SIGNATURE

DATE

CERTIFICATION

This is to certify that this research work was carried out by ANEDU Isioma , with the matriculation number ENV1904029, in partial fulfillment of the requirements for the award of Bachelor of Science Degree in Architecture (B.Sc. Architecture), Faculty of Environmental Sciences University of Benin City, Edo State, Nigeria.

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DEDICATION

This project is dedicated to God Almighty and also my parents MR. AND MRS IKECHUKWU ANEDU.

ACKNOWLEDGEMENT

I hereby acknowledge God's faithfulness to me throughout the research work. I am eternally grateful to God who created the heavens and the earth and who gave me the strength to accomplish this research. The success of this study remained dependent on God's help, His divine protection, guidance, provision and sustenance throughout the period of the study.

I also wish to acknowledge the roles of my supervisor Arc. Cecilia O. Atohengbe in ensuring that this study comes to completeness.

Greatly, I appreciate my parents Mr and Mrs Ikechukwu Anedu and my siblings for all their support, care, help and provision during the research period. God bless you all!

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ABSTRACT

The construction industry faces increasing challenges in achieving sustainable, ecofriendly practices while meeting the growing demand for housing. This research project explores the viability of rammed earth as a substitute replacement for sandcrete and concrete in building construction in Ekosodin, Edo State, Nigeria. Rammed earth, an ancient construction material requiring special technique, offers significant potential for sustainable building due to its low environmental impact, availability of raw materials, and thermal mass properties. The research will encompass a comprehensive analysis of rammed earth's structural performance, thermal efficiency, and cost-effectiveness in the context of Edo State's climate and local construction practices. By examining the technical, economic, and environmental aspects of rammed earth construction, this research aims to provide valuable insights and recommendations for promoting its adoption as a sustainable building material in Edo State, ultimately contributing to the region's sustainable development goals.

CHAPTER ONE

1.0 INTRODUCTION

This research examines RAMMED EARTH as a substitute for sandcrete and concrete in building construction the geographical location of Ekosodin , Benin City, Edo state in Nigeria West Africa. It examines building material with the primary focus on Rammed Earth and it seeks to educate people on the importance, durability and sustainability of the material in the construction of residential buildings using Benin City as a geographical case study.

1.1 BACKGROUND OF THE STUDY

1.1.1. RAMMED EARTH

Rammed earth is a type of composite material in which a mixture of gravel, sand, clay, and earth is tightly compressed using a construction machinery known as a tamper to create sturdy walls. This method necessitates tedious preparation, careful soil selection, and precise execution. Starting with the selection of correct soil that has the ideal ratio of clay, sand, and gravel for optimal compaction and structural stability, rammed earth walls are built. There may be a number of soil types available in different places, resulting in walls with unique properties.

The ideal moisture content is then achieved by combining the selected soil with water of appropriate quantity. The mixture's ability to be worked and subsequent compaction depend on the moisture content, which is essential. To enable for good compaction, the mixture needs to be moist but not overly so.

Formwork, which comprises wooden or metal frames, is set up to determine the size and shape of the walls. During compaction, the formwork acts as a mould to keep the rammed earth mixture in place.

Depending on the desired design and structural needs, walls can be built vertically or in layers.

Ramming is the process of compacting the mixture into the formwork either manually or mechanically. Traditionally, the earth mixture is compressed with wooden tampers or rammers. Before adding the next layer, the previous one is completely compacted, removing air spaces and increasing wall density for strength and stability.

In contemporary construction, mechanical devices such as hydraulic presses or pneumatic rammers may be used to increase compaction rates and guarantee uniform density throughout the walls.

The walls undergo a curing process after being properly rammed. This allows the particles to adhere to one another and form a cohesive mass as the rammed earth mixture gradually dries and solidifies.

Depending on the temperature and soil characteristics, curing times vary. Once cured, rammed earth

walls have a number of beneficial qualities. They have excellent thermal mass, which may store heat and increase energy efficiency by regulating indoor temperatures. These walls are also fire resistant and sound-insulating, demonstrating their sturdiness and tenacity.

Rammed earth construction is sustainable in terms of its impact on the environment. It uses materials that are readily available nearby, avoiding the need for long-distance travel and the related carbon emissions. Rammed earth structures can be kept up and have a small carbon footprint.

1.1.2 RESIDENTIAL BUILDING

Residential buildings are designed and constructed structures intended for human habitation, serving as homes or dwellings for individuals, families, or households. Their main objective is to give people a place to live that can be private and protected from the outside world.

These structures come in a wide variety of shapes, sizes, and architectural designs, ranging from singlefamily homes to complexes with many apartments and condominiums. They may be standalone independent buildings or a component of bigger residential developments or communities.

Residential buildings are thoughtfully designed and constructed to accommodate different aspects of life every day. They consist of places and features including living rooms, kitchens, lobby, dining area, baths, study and storage spaces. The spaces should have emphasis on comfort and functionality of the space.

1.1.3 BENIN CITY IN NIGERIA

Benin City, located in southern Nigeria, is the capital of Edo State and one of the oldest cities in Nigeria. It has a rich history, being the centre of the ancient Benin Kingdom, renowned for its art, culture, and political influence. Historically, Benin City is the capital of the Benin Empire, which existed from the 13th to the 19th century. The kingdom had a well-developed administrative system, remarkable bronze artwork, and a vibrant cultural heritage that still influences the city today. One of the prominent landmarks in Benin City is the Benin Royal Palace, also known as the Oba's Palace. It serves as the residence of the traditional ruler, the Oba of Benin, who holds significant cultural and ceremonial importance in the region.

One of the notable architectural features in Benin City is the use of red earth walls, commonly referred to as "mud walls." These walls are constructed using locally sourced clay and earth materials, which are mixed with water and compacted to form sturdy walls. Mud walls provide natural insulation, helping to regulate indoor temperatures in the region's tropical climate. The traditional houses in Benin City often feature intricately carved wooden doors and pillars. These

carvings showcase the exceptional artistic skills and cultural symbolism of the Edo people. The motifs and patterns found in the carvings depict historical events, religious beliefs, and ancestral connections.

1.2 STATEMENT OF THE PROBLEM

High carbon dioxide (CO₂) emission of concrete, corrosion and high thermal conductivity of steel, limited insulation and moisture absorption of brick and masonry. Concrete is a building material that is made up of cement, fine and coarse aggregates and water. Fine aggregates are natural sand that can pass through a 5mm sieve while a coarse aggregate are natural stones that cannot pass through a 5mm sieve. Cement is a binding material used in construction to bind various building materials together and form a solid structure. It is a crucial component of concrete and other cementitious materials commonly used in building and infrastructure projects. The most commonly used type of cement is Portland cement, which is made by grinding clinker (a mixture of limestone, clay, and other materials) into a fine powder. Cement manufacture involves the heating of raw materials at high temperatures in a cement kiln. This procedure is required for the production of clinker, an essential part of cement. However, the high temperatures are achieved by burning fossil fuels, which emit huge amounts of carbon dioxide (CO₂). As a result, cement production contributes significantly to global carbon emissions and climate change. Rammed Earth on the other hand has low emissions of carbon dioxide which is harmful to the environment. Sandcrete, a common construction material poses environmental concerns due to the depletion of natural aggregates and high energy in its construction production.

Brick and masonry are porous construction materials, which means they have little spaces or openings within them that can take in moisture from the air. Bricks can absorb water through these spaces when exposed to precipitation, groundwater, or high humidity. A common issue with moisture in brickwork is efflorescence. When water enters a brick, it dissolves any soluble salts that are there and then transports those salts to the brick's surface. The salts are left behind as the water evaporates and settle on the surface of the brick as a white, powdery coating. Efflorescence not only detracts from the brickwork's beauty, but it may also be a sign of persistent moisture-related problems.

Wood is a material that has the ability to burn or combust, the fire susceptibility of wood can pose safety risks in building construction.

After discussing these building materials, it appears that they have adverse impacts on building structure, which can be minimized by using a more sustainable material. Rammed earth is a material that has low carbon dioxide (CO₂), it doesn't corrode when exposed to moisture and it doesn't

absorb or releases so much heat into a building. It has good fire resistance quality and is not affected by pests or termites.

1.2 AIMS AND OBJECTIVES

This study aims to undertake a thorough assessment of rammed earth's structural viability, positioning it as a potential substitute for conventional building materials like concrete and sandcrete in residential building construction Benin City and educate architects, construction team and the public on the importance and value of Rammed Earth building as a suitable building material.

Objectives of the study are to;

- i. Study what factors distinguish Rammed Earth as a sustainable building material.
- ii. Study the effect of the Benin City bioclimatic conditions on the usage and durability of the Rammed Earth as a building material.
- iii. Study the advantages in the choice of using Rammed Earth in the residential building construction process.

1.4 SCOPE OF STUDY

The scope of this study covers residential buildings with aim of educating people; architects, engineers and clients alike on the value of rammed earth-based sustainability and durability. Extensively the study will be looking at:

- a) What type of building material the rammed earth is?
- b) The relevance of rammed earth to residential buildings in Benin City?
- c) The sustainability and durability of this material in the residential building construction process?
- d) The effect of climate on the sustainability of the building material?

Conclusively, the study considers the possibility of constructing sustainability and long-lasting residential buildings with rammed earth irrespective of the climatic changes in the Benin City geographical area.

1.3 RESEARCH HYPOTHESIS

The following hypothesis are stated in null form;

- i. What distinguishes rammed earth as a sustainable building material?
- ii. What is rammed earth building material? iii. Will the climate of Benin City affect the rammed earth building material?
- iv. How durable and sustainable is this material?
- v. Why do residential buildings require rammed earth in construction?

1.4 LIMITATIONS

Some of the limitations of this study are stated below;

- i. Lack of awareness and knowledge of rammed earth.
- ii. Lack of expertise.
- iii. Lack of modern equipment

1.5 SIGNIFICANCE OF THE STUDY

The importance of this study is that, it reveals to the architect, engineer and other persons in the building construction team that the rammed earth material is a sustainable and durable building material in the construction industry. It also helps the architects as well as the clients to know about the best of materials used in construction for long-lasting residential buildings.

Conclusively, this study is significant for enlightenment and further understanding of rammed earth as a building material in the construction industry.

CHAPTER TWO

2.0 LITERATURE REVIEW

Over the years, building material has evolved in the construction industry which has resulted in the modernization of wood, bamboo, steel, concrete, glass, fibre and others which has a great impact in the construction industry. This impact has led several scholars in this field to successfully document their findings in books, articles, journals, tapes and other form of documentation.

This chapter examines the findings, contribution and review of these scholars as regards building materials in the construction industry.

The chapter is split into 3 parts which are: Review of Concepts, Previous Studies and Present Study.

2.1 REVIEW OF CONCEPTS

This section reviews the major concepts that were employed in this research. Some of these concepts include: Rammed Earth, Residential Buildings and Sustainability of the Material.

2.1.1 RAMMED EARTH

According to Arslan et al. (2017), “Rammed earth is a renewable and clean energy raw material formed by the artificial ramming of natural soil.” He also added that it is a “renewable and clean energy raw material.”

This implies that the material has proven to be one of the oldest building materials in history in terms of its benefit in construction, availability and bioclimatic conformity. Due to its form of construction, it is low-cost and very affordable for the common client who desires to get a sustainable and durable building structure. Shenwei Yu et al (2022:1) also states that the rammed earth, furthermore referred consecutively as RE, is “a low-tech recyclable building material with good heat storage and moisture absorption performance that can better maintain the stability of the indoor thermal environment and improve indoor comfort. With innovations in and the development of new technology, the field of rammed earth construction technology is gradually expanding.”

Rammed earth construction is a vernacular technique which is attracting renewed interests throughout the world today. A rammed earth wall is manufactured by compacting a clayey soil (earth) into a formwork. The earth composition varies greatly but contains no organic component and enough clay which acts as a binder between the grains, a mixture of silt, sand,

gravels and stones with a diameter of few centimetres. Compaction is performed using a water content considered as optimum i.e providing the highest dry density for a fixed compaction energy. This process is called the dry method because the water content is around 10%, while a paste (in case of mortar or adobes) should have a water content of about 25%. The rammed earth is composed of several layers of earth. The earth is poured in layers of about 15 cm thick into a formwork (wooden or metal). It is rammed with a rammer (manual or pneumatic). After compaction, the thickness of each layer is about 10cm. The procedure is repeated until the desired height of the wall is obtained. Traditionally, the material used to manufacture rammed earth walls is the natural earth on the site. (Bui et al, Morel et al, Hans et al, Do et al, 2011:2)

2.1.2 RESIDENTIAL BUILDINGS

According to the National Building Code of India, “a residential building includes any building that comes with sleeping accommodation for normal residential purposes, without or with dining and cooking facilities.” Residential buildings can be of the following classifications: i. Hotels.

ii. Apartment houses or flats.

iii. Dormitories. iv. 1 or 2-family private dwellings. v.

Lodging or rooming houses.

According to (Architects, n.d), “A residential building is a building where people live, it is a place used for dwelling purposes and provided with sleeping facilities. It also gives shelter from harsh environmental conditions. The housing market is at the top in demand because everyone requires some living space in their life.”

2.1.3 SUSTAINABILITY OF THE MATERIAL

Speaking on sustainability, Mahdavinejad (2014) states that; “Sustainability is comprehensive therefore a complex subject. It is of vital importance to all because it deals with the survival of human species and almost every living creature on the planet. Sustainable and eco-friendly architecture is one of the main aims that humans requires for creating a better life and have made as the ultimate model for all their activities. For this reason, moving towards a greener architecture is well thought-out as the main goal of the present architecture of our time.”

This concept of sustainability seemed to have a different facet at each turn and there were specifications on the areas of sustainability been addressed. This research here studies the concept of sustainable building materials and construction processes. According to Team (2020), “The construction industry is one of the largest users of global resources and contributors of

pollution. It therefore has a huge responsibility to aid sustainability. But what exactly is sustainable construction and what are the benefits?”

He went on further to talk about the role of sustainable construction in place where he said; “Sustainable construction means building with renewable and recyclable resources and materials. During construction projects, care must be taken to reduce waste and energy consumption where possible and protect the natural environment around the site. The end result of a sustainable construction project must be an environmentally friendly building or environment.”

Ben (2022:14) advises that Sustainability as a concept, “has no straight forward solution, especially considering that sustainability is a goal for all to reach as they continually strive to reach towards it.”

2.2 PREVIOUS STUDIES

This section examines previous works that has been done by different authors, scholars and the relevance to the current topic.

Liang Liu et al (2023) in studies about the rammed earth building material and weather/bioclimate conditions, states that Rammed earth is a green material that is widely used in all kinds of buildings around the world. The Great Wall of Shanhaiguan is a typical world cultural site built of rammed earth. The Great Wall of Shanhaiguan was built during the Ming Dynasty. The wall is mainly composed of bricks externally and rammed earth internally. After hundreds of years of extreme weather conditions, the bricks of some sections of the Great Wall fell away, leaving only the rammed earth walls. Under the action of longterm rainwater erosion, wall erosion and collapse caused serious and irreversible damage to historical relics. Therefore, it is necessary to pay attention to the erosion resistance of the rammed earth Great Wall.



Fig. 1 / Source: Great Wall of Shanhaiguan

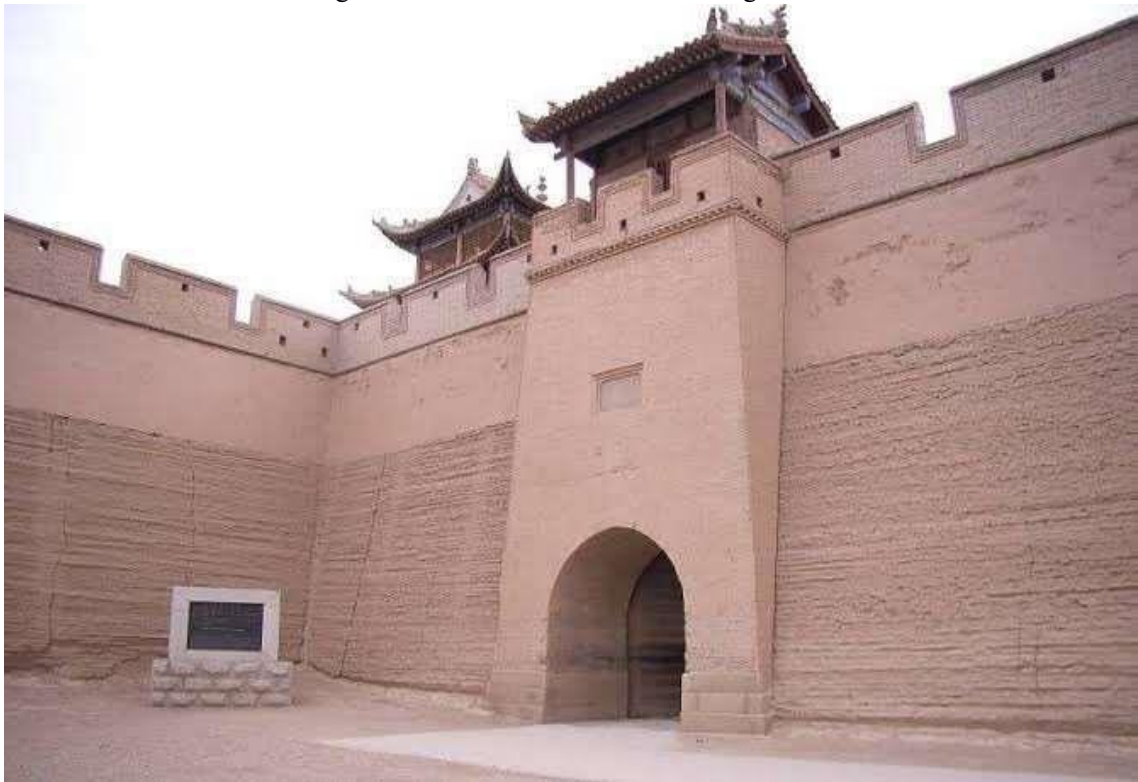


Fig. 2 / Source: Exterior View of Great Wall of Shanhaiguan



Fig. 3 / Source: Over view of Great Wall of Shanhaiguan Adolfo Preciado and Juan Carlos Santos (2020) on the benefit of rammed earth and seismic conditions says that the Rammed earth is one of the oldest materials of the world and has been used as a building material for centuries due to its availability in the near environment, zero-cost benefits, auto-construction and bioclimatic capabilities. These bioclimatic benefits of rammed earth permit the users to sustain extreme hot weathers in spring and summer, as well as to survive cold seasons in winter.

Wiçal Cheikhi; Khadija Baba; Sidi Mohamed Lamrani; Abderrahmane Nounah; Mohamed Khalfaoui; Lahcen Bahi (2018) stated that “Since the beginning of its use in the construction industry, the rammed earth always proved its reliability as much as local, ecological material, implementing excellent thermal properties. Indeed, whatever the climatic context of their establishment, rammed earth constructions are able to get freshness in summer and tepidity in winter. This property makes it possible to reduce the recourse to the systems of air-conditioning and heating, leading to an abusive consumption of energy.

In a world context centered on sustainable development and energy efficiency, working to reduce the energy consumption of the buildings becomes a major requirement.”

2.3 PRESENT STUDY

This research dissertation sets out to examine and describe the sustainability of the rammed earth as a durable building material.

Building Material Sustainability according to this study should be seen as an enlightenment of the vast benefits that the rammed earth can offer in the construction process of rammed earth houses.

CHAPTER THREE

RESEARCH METHODOLOGY

1.0 INTRODUCTION

This chapter gives details on the methods used in collection of data and tactics used in carrying out the research. Methodology shows the practical steps which the researcher employed in gathering the unprocessed or raw data for the analysis.

3.1 RESEARCH DESIGN

In this research design, the use of questionnaire will be utilized. The questionnaire as a research tool made up of list of several questions meant to collect data and information from respondents. One could consider questionnaires to be a form of written interview. The questionnaire will be administered in-person, over the phone, online, or by mail. This method enables a quick, simple, and effective way to collect a lot of data from a large sample of people.

3.2 POPULATION AND SAMPLING TECHNIQUES

The population of respondents considered for the questionnaire is that of Benin City. And based on the nature or research topic, “A Study of Rammed Earth as a Substitute for Concrete and Sandcrete Construction in Edo State” Architects and Quantity Surveyors are the main professionals in the construction industry or the built environment made up the study population. The choice of this subsector is justified by the fact that materials that have less carbon emission and provide a safe environment and sustainable residential buildings. These professionals (architects and quantity surveyors) and even students in these fields has an in-depth knowledge on construction processes and overall cost implications of rammed earth thereby forming the respondents of the questionnaire

3.3. SAMPLE SIZE

During the process of sending out questionnaires, a total number of 75 persons were reached out to and the number of responses received is 60 thereby getting a response rate of 80%.

3.4. METHODS OF DATA COLLECTION

In order to describe the respondents who took part in the study and to illustrate the general trend of the results on the many variables that were looked at, frequency counts of the responses were obtained. Tables and percentages were used in the data analysis to summarize the substantial

volumes of data and make the report readable. Descriptive statistics were used to arrange, code, and evaluate the data (pie chart, table, percentages).

3.5. DATA COLLECTION ETHICS

It is placed into consideration the rights of respondents when collecting data so as to avoid any form of ethical issues so as to arrive at an unbiased situation as much as possible. This will help us to ensure that the research is not causing undue harm to respondents and their privacy is protected.

Some of the data collection ethics employed in the process of this research

include; Informed consent of individuals. Protected privacy of individuals.

Transparent data collection.

Fair and unbiased data collection.

Use of the data collected for the specific purpose.

RESPONSE RATE

Sent Questionnaire	Received Questionnaire	Response Rate
75	60	80%

Table 3.1 shows the response rate from the questionnaires sent out

From the table above, out of a total of 75 questionnaires sent out to the public, 60 responses were received thereby obtaining a response rate of 80%.

CHAPTER FOUR 4.1. DATA ANALYSIS AND PRESENTATION

This chapter analyses the results of this research. The research involved a questionnaire in a digital form (google form) which had about 60 stakeholders/specific audience respondents in the case study's environment out of the 75 respondents sent out.

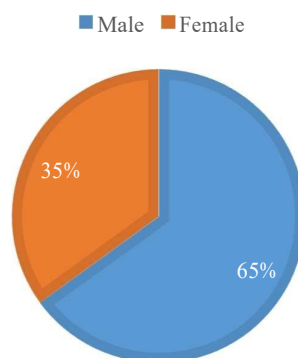
4.2. SURVEY QUESTIONS AND RESPONSES

I. Gender of Respondents *

Table 4.1 shows the gender distribution of respondents.

Responses	Frequency	Percentage
Male	39	65
Female	21	35
Total	60	100

Figure 4.1 shows the age distribution of respondents

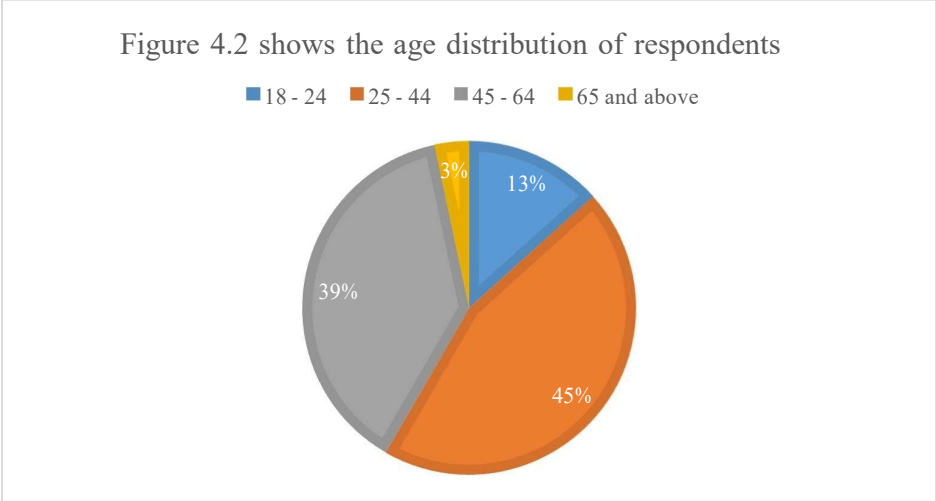


From the analysis above, out of the total respondents of 60, 39 respondents or 65% of the respondents are male while 21 respondents or 35% of the respondents are female.

II. Age Distribution of Respondents *

Table 4.2 shows the age distribution of respondents.

Responses	Frequency	Percentage
18 – 24	8	13.3
25 – 44	27	45
45 – 64	23	38.3
64 and above	2	3.4
Total	60	100

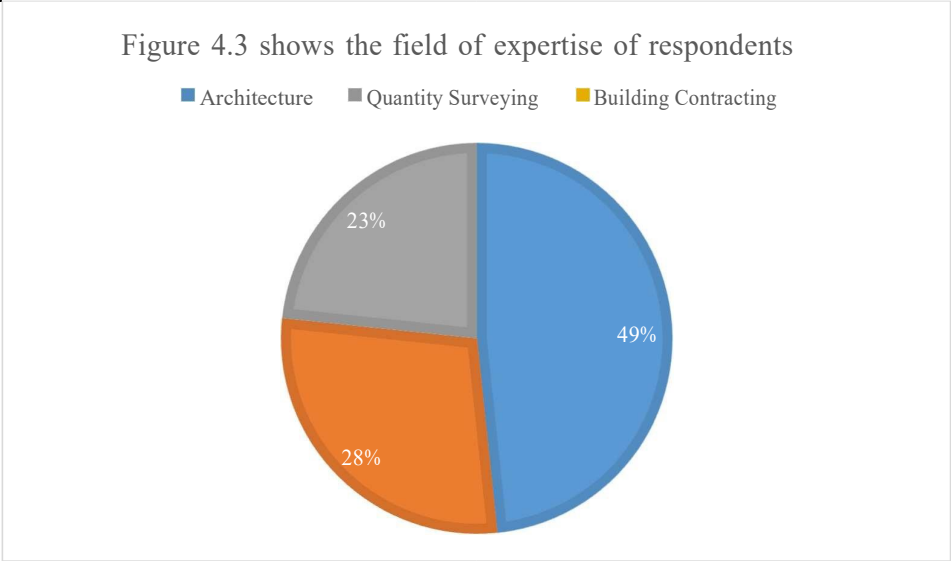


From the analysis above, out of the total of 60 respondents, 8 respondents or 13.3% of the respondents are between 18 – 24 years, 27 respondents or 45% of the respondents are between 25 – 44 years, 23 respondents or 38.3% of the respondents are between 45 – 64 years and finally, 2 respondents or 3.4% of the respondents are 65 years and above of age.

III. Field of Expertise *

Table 4.3 shows the field of expertise of respondents.

Responses	Frequency	Percentage
Architecture	29	48.3
Quantity Surveying	17	28.3
Building Contracting	14	23.4
Total	60	100

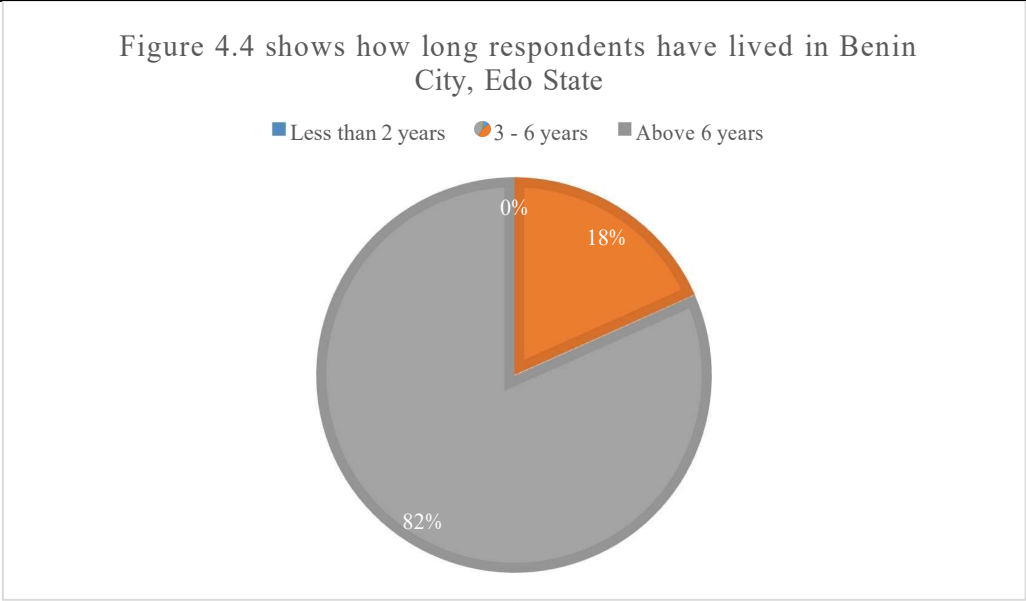


From the analysis above, out of the total 60 respondents, 29 respondents or 48.3% of the respondents are in architecture field, 17 respondents or 28.3% of the respondents are in quantity surveying field while 14 respondents or 23.4% of the respondents are building contractors.

IV. How long have you lived in Benin City, Edo State? *

Table 4.4 shows how long respondents have lived in Benin City, Edo State.

Responses	Frequency	Percentage
Less than 2 years	0	0
3 – 6 years	11	18.3
Above 6 years	49	81.7
Total	60	100



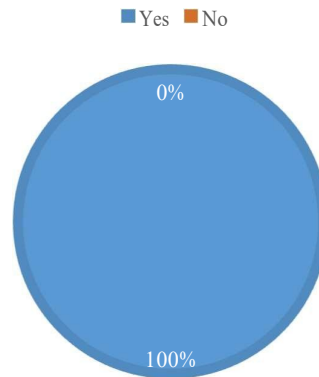
From the analysis above, out of the total 60 respondents, none of the respondents have lived in Benin City for a minimum of 2 years, 11 respondents or 18.3% of the respondents have lived in Benin City between 3 – 6 years and finally, 49 respondents or 81.7% of the respondents have lived in Benin City for above 6 years.

V. Have you heard of rammed earth construction? *

Table 4.5 shows responses of respondents who have heard about rammed earth construction.

Responses	Frequency	Percentage
Yes	60	100
No	0	0
Total	60	100

Figure 4.5 shows respondents who are aware of rammed earth construction



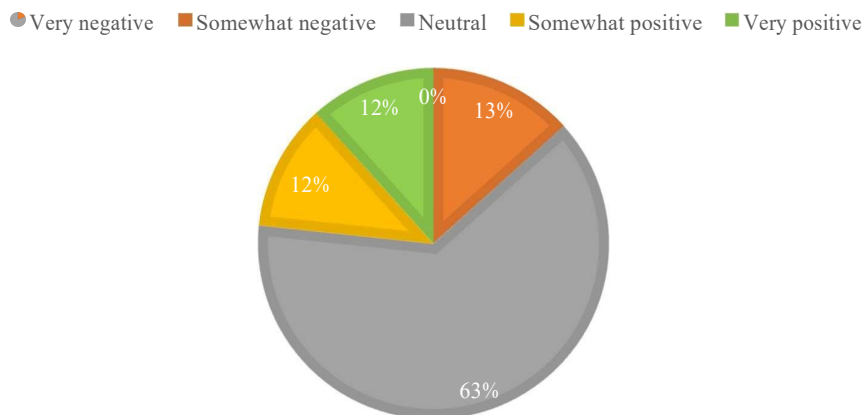
From the analysis above, out of the total 60 respondents, none of the respondent is ignorant of rammed earth construction. So, the total 60 respondents or 100% of respondents are aware of rammed earth construction.

VI. What is your perception of rammed earth construction? *

Table 4.6 shows responses of respondents' perception of rammed earth construction.

Responses	Frequency	Percentage
Very negative	0	0
Somewhat negative	8	13.3
Neutral	38	63.3
Somewhat positive	7	11.7
Very positive	7	11.7
Total	60	100

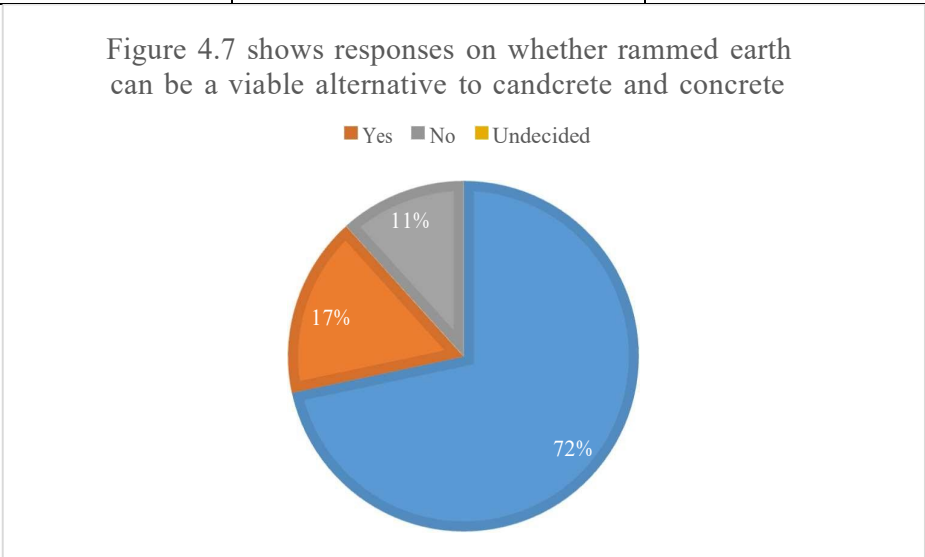
Figure 4.6 shows the perception of respondents on rammed earth construction



From the analysis above, out of the total 60 respondents, none of the respondents perceive rammed earth construction to be very negative, 8 respondents or 13.3% of the respondents perceive rammed earth construction to be slightly or somewhat negative, 38 respondents or 63.3% of the respondents perceive rammed earth construction to be neutral and finally 7 respondents or 11.7% of the respondents each perceive rammed earth construction to be slightly or somewhat positive and very positive.

VII. Do you think rammed earth can be a viable alternative to sandcrete and concrete? * Table 4.7 shows responses on whether rammed earth is a viable alternative compared to sandcrete and concrete.

Responses	Frequency	Percentage
Yes	43	71.6
No	10	16.7
Undecided	7	11.7
Total	60	100

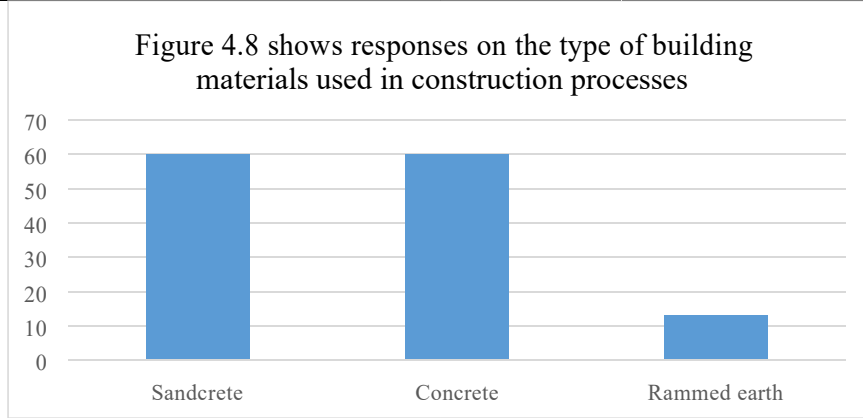


From the analysis above, out of the total 60 respondents, 43 respondents or 71.6% of the respondents think that rammed earth can be a viable alternative to sandcrete and concrete, 10 respondents or 16.7% of the respondents think that rammed earth cannot be a viable alternative to sandcrete and concrete and 7 respondents or 11.7% of respondents are undecided on whether rammed earth can be a viable alternative or not.

VIII. What type of building materials do you currently use for construction processes? (select all that apply). *

Table 4.8 shows responses on the type of building materials currently used for construction processes.

Responses	Frequency	Percentage
Sandcrete	60	100
Concrete	60	100
Rammed earth	13	21.7

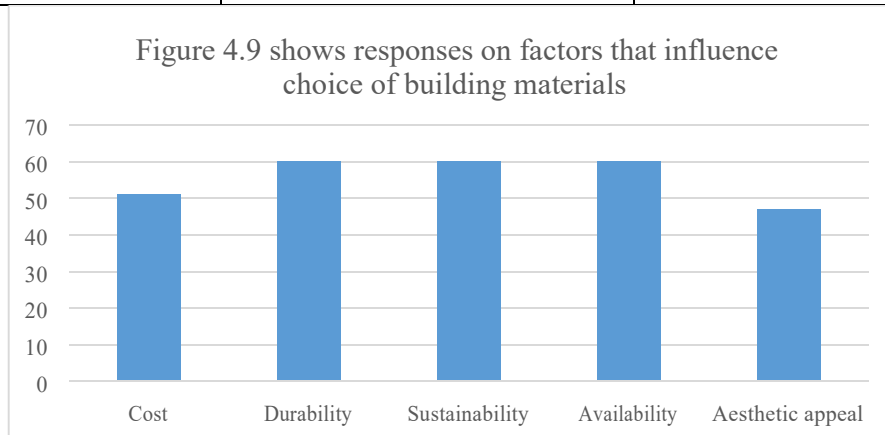


From the analysis above, out of the total 60 respondents, all the respondents currently use sandcrete and concrete as building materials in their construction processes while only 13 respondents or 21.7% of the respondents use rammed earth as a building material in their construction processes.

IX. What are the factors that influence your choice of building materials? (select all that apply)

* Table 4.9 shows responses on the factors that influence the choice of building materials.

Responses	Frequency	Percentage
Cost	51	85
Durability	60	100
Sustainability	60	100
Availability	60	100
Aesthetic appeal	47	78.3

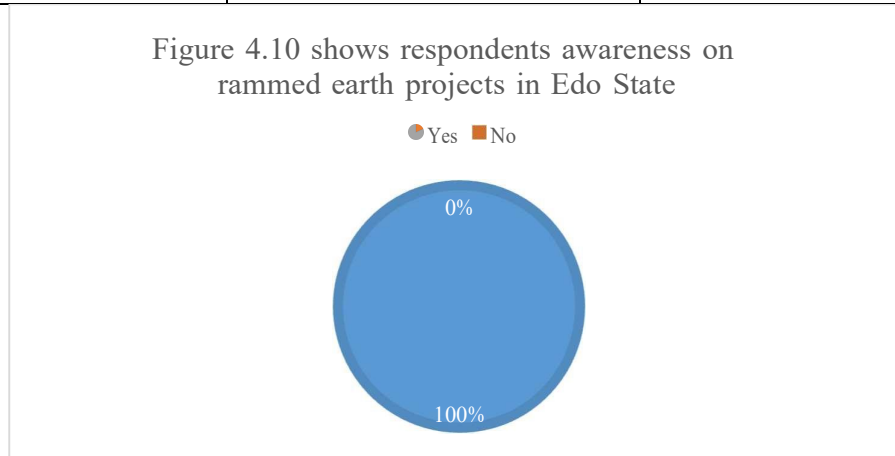


From the analysis above, out of the total 60 respondents, 51 respondents or 85% of the respondents agree that cost is an influencing factor in the choice of building materials, all the 60 respondents agree that durability, sustainability and availability are factors influencing the choice of building materials and finally, 47 respondents or 78.3% of respondents agree that aesthetic appeal is an influencing factor affecting the choice of building materials.

X. Are you aware of any rammed earth construction projects in Edo State? *

Table 4.10 shows responses of respondents' awareness on any rammed earth construction projects in Edo State.

Responses	Frequency	Percentage
Yes	60	100
No	0	0
Total	60	100

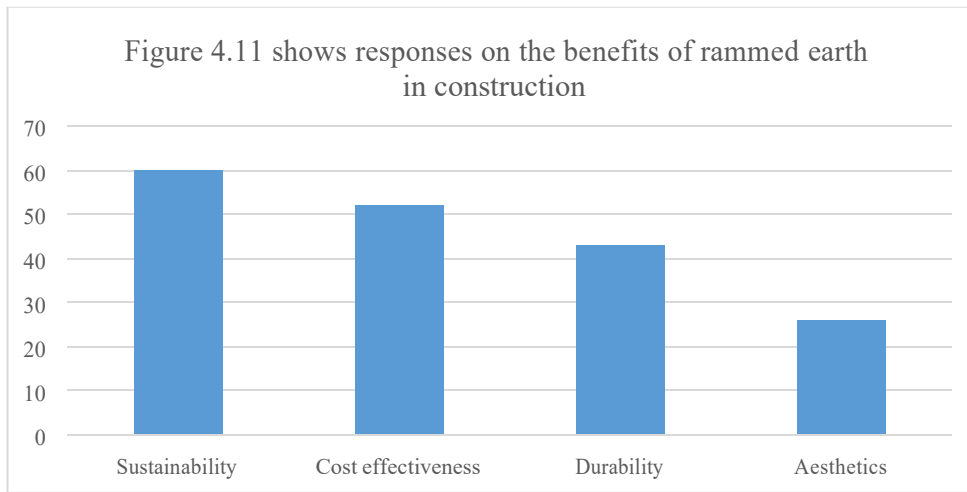


From the analysis above, out of the 60 respondents, none of the respondents is ignorant or unaware of rammed earth construction projects in Edo State as the total 60 respondents are aware of at least one construction project going on in Edo State that involved rammed earth.

XI. What do you think are the benefits of rammed earth in construction? (select all that apply)

* Table 4.11 shows responses on the benefits of rammed earth in construction.

Responses	Frequency	Percentage
Sustainability	60	100
Cost effectiveness	52	86.7
Durability	43	71.7
Aesthetics	26	43.3

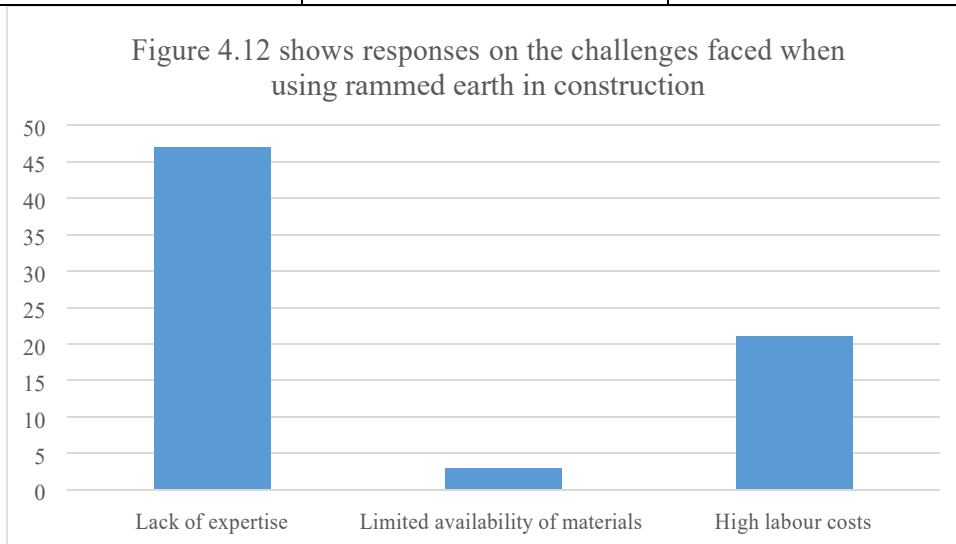


From the analysis above, out of the 60 respondents, the total 60 respondents agree that sustainability is one of the benefits of rammed earth in construction. 52 respondents or 86.7% of the total respondents agree that cost effectiveness is another benefit of rammed earth in construction. 43 out of 60 respondents or 71.7% of the total respondents agree that durability is one of the benefits of rammed earth in construction. Finally, 26 out of 60 respondents or 43.3% of respondents agree that aesthetics is a benefit of rammed earth in construction.

XII. What are the challenges of using rammed earth in construction? (select all that apply) *

Table 4.12 shows responses on the challenges of using rammed earth in construction.

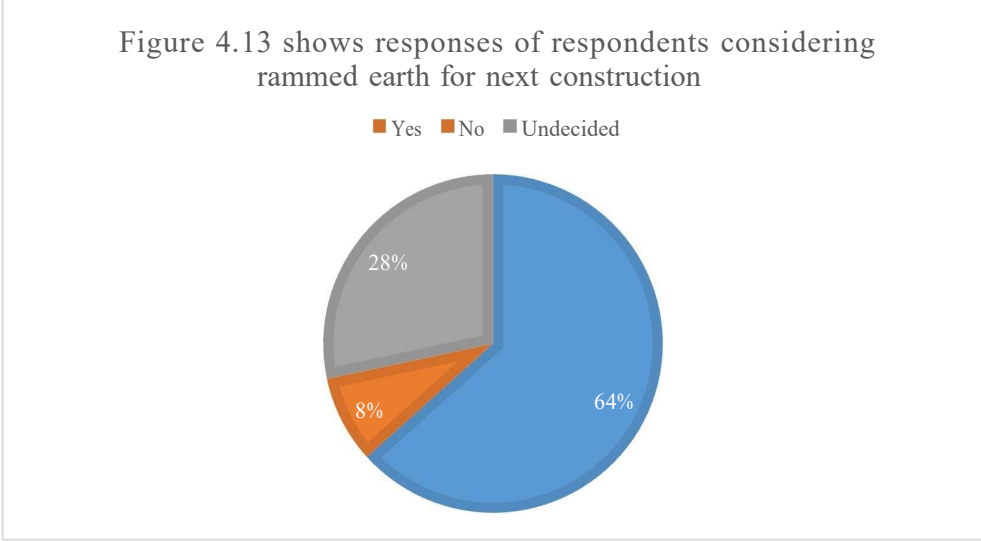
Responses	Frequency	Percentage
Lack of expertise	47	78.3
Limited availability of materials	3	5
High labour costs	21	35



XIII. Would you consider using rammed earth for your next construction? *

Table 4.13 shows responses of respondents on whether they'll consider using rammed earth in their next construction.

Responses	Frequency	Percentage
Yes	38	63.3
No	5	8.4
Undecided	17	28.3
Total	60	100

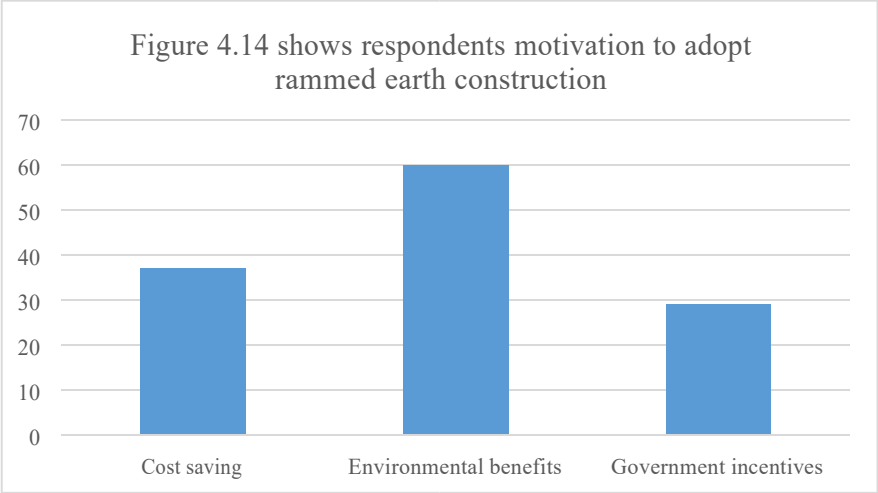


From the analysis above, out of the 60 respondents, 38 respondents or 63.3% of the respondents are willing to incorporate rammed earth for their next construction, 5 respondents or 8.4% of respondents are unwilling or not ready in considering using rammed earth for their next construction and 17 respondents or 28.3% of the respondents remain undecided on whether or not they will be considering rammed earth for their next construction.

XIV. What would motivate you to adopt rammed earth construction? (select all that apply) *

Table 4.14 shows responses of respondents on what motivate them to adopt rammed earth construction.

Responses	Frequency	Percentage
Cost savings	37	61.7
Environmental benefits	60	100
Government incentives	29	48.3



From the analysis above, out of the total 60 respondents, 37 respondents or 61.7 % of the total respondents are motivated in adopting rammed earth construction because of its cost saving on a long run. The whole 60 respondents are motivated in adopting rammed earth construction because of its environmental benefits. Finally, 29 respondents out of 60 total respondents or 48.3% of the respondents are motivated to adopt rammed earth construction because of government incentives.

APPENDIX

A STUDY OF RAMMED EARTH AS A SUBSTITUTE FOR CONCRETE AND SANDCRETE CONSTRUCTION IN EDO STATE

My name is Anedu Isioma, a 400-Level student of the Department of Architecture, Faculty of Environmental Sciences, University of Benin, Benin City, Edo State. Conducting a research on the topic, “A Study of Rammed Earth as a Substitute for Concrete and Sandcrete Construction in Edo State.”

As part of my project, I am gathering data through this questionnaire to understand the views of various construction professionals, like the architects, quantity surveyors and building contractors concerning this topic of using rammed earth as a substitute for concrete and sandcrete in construction in Edo State. In a society where traditional building materials like concrete and sandcrete often have high environmental impacts, there is a pressing need for sustainable and eco-friendly materials which has brought about this study on rammed earth as an alternative building material based on versatility and performance.

Your participation in this survey is crucial to understanding the feasibility and potential barriers involved in rammed earth as a building material in building construction in Benin City and Nigeria in general. The questionnaire should take approximately 5 to 10 minutes to complete.

All responses will be kept confidential and used solely for academic purposes. Your participation is voluntary and you may withdraw at any time without penalty.

1. Gender * Male Female
2. Age Distribution * 18 – 24 years 25 – 44 years 45 – 64 years 65 years and above
3. Field of Expertise * Architecture Quantity Surveying Building Contracting
4. How long have you lived in Benin City, Edo State? * Less than 2 years 3 – 6 years
 Above 6 years
5. Have you heard of rammed earth construction? *
 Yes No
6. What is your perception of rammed earth construction? * Very negative Somewhat negative Neutral Somewhat positive Very positive
7. Do you think rammed earth can be a viable alternative to sandcrete and concrete? *
 Yes No

Undecided

d

8. What type of building materials do you currently use for construction processes? (Select all that apply) *
- Concrete
 - Sandcrete
 - Rammed earth
9. What are the factor(s) that influence your choice of building materials? (Select all that apply) *
- Cost
 - Durability
 - Sustainability
 - Availability
10. Are you aware of any rammed earth construction projects in Edo State? *
- Yes
 - No
11. What do you think are the benefit(s) of rammed earth in construction? (Select all that apply) *
- Sustainability
 - Cost effectiveness
 - Durability
 - Aesthetics
12. What are the challenge(s) of using rammed earth in construction? (Select all that apply) *
- Lack of expertise
 - Limited availability of materials
 - High labour costs
13. Would you consider using rammed earth for your next construction? *
- Yes
 - No
 - Undecided
14. What would motivate you to adopt rammed earth construction? (Select all that apply) *
- Cost saving
 - Environmental benefits
 - Government incentives

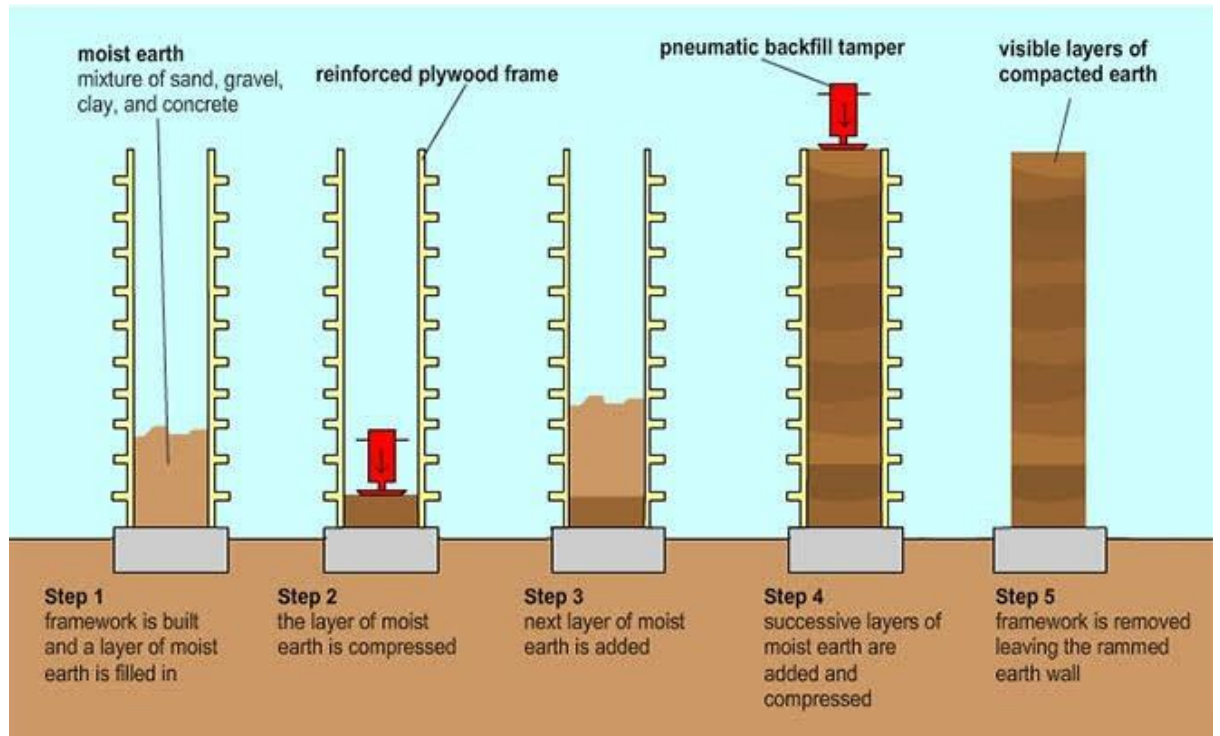


Fig. 14 / Source: Construction process



Fig. 15 / Source: Compaction process of Rammed Earth



Fig. 16 / Source: Compaction process of Rammed Earth

4.3. REAL-LIFE BUILDINGS CONSTRUCTED WITH RAMMED EARTH



Fig. 17 / Source: Rammed Earth Building Under Construction



Fig. 18 / Source: Rammed Earth Building Under Construction



Fig. 19 / Source: Oba Palace of Benin



Fig. 20 / Source: Oba Palace of Benin



Fig. 21 / Source: Oba Palace of Benin



Fig. 17 / Source: Exterior view of the Oba Palace

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. INTRODUCTION

This chapter includes the study's summary, conclusions and recommendations.

5.2. SUMMARY

Chapter One of this research begins with an introduction of the general concepts involved in the research topic and also gives a background study which links to Chapter Two, where research was reviewed and previous and present studies were considered respectively which involved presenting knowledge contributions from other architects and scholars or authors on the subject matter.

Chapter Three entails the presentation of the Research Methodology which involves presenting the Research Design, the Research Strategies and the Method of Data Collection.

In Chapter Four, the Data which was collected via a questionnaire/survey form analysed and extensive explanation was given at each analysis level. In, Chapter Five, according to this study, it was discovered that;

1. Rammed earth is a type of structure in which a mixture of gravel, sand, clay, and earth is tightly compressed using construction machinery known as a tamper to create sturdy walls which is durable and sustainable for residential building construction.
2. According to Architect Rakun, "Rammed earth as a construction material needs more publicity and awareness so clients, architects, engineers and contractors can make good use of for construction project".
3. Universities and tertiary institutions should incorporate the construction process of rammed earth into an area of discipline such as architecture and civil engineering so they can have the skill, knowledge and expertise of this material.
4. According to Engineer Efosa, "It is a labour-intensive endeavour and it's also a timeconsuming process". Rammed earth required skilled personnel for its construction processes.

5. According to Engineer Benedict, “Rammed earth is a sustainable building material due to its use of abundant, local resources, low embodied energy, thermal mass properties, longevity, low maintenance, non-toxic nature, recyclability, and potential for local job creation. It offers eco-friendly construction while maintaining an aesthetically pleasing, natural appearance.”

5.3. CONCLUSION

Conclusively, it can be deduced that RAMMED EARTH is a sustainable and durable building material for modern residential and other building construction as proven by the result of the presented data via the questionnaire in this work.

5.4. RECOMMENDATIONS

From the summary, findings and conclusion from this research, below are some recommendation;

1. More exposure and awareness on the rammed earth material be carried out to enlighten the general public on the concept, sustainability, durability and efficient significance of the material.
2. Architects, Civil Engineers, Structural Engineers Quantity Surveyors etc alike should carefully consider a building project in terms of climatic condition, foundation structure, building design or aesthetics and recommend rammed earth to the client where applicable.
3. University disciplines such as Architecture, Civil Engineering, Structural Engineering and Quantity Surveying, should incorporate precise education on the construction process of the rammed earth building.

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