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RESEARCH ARTICLE

Adopting Stabilized Earth Construction to Address Urban Low-cost Housing Crisis in Jos, Nigeria

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Abstract

Shelter is one of the basic needs of mankind, while housing is a form of shelter which has profound impact on health, welfare and productivity of individuals. In developing nations (such as Nigeria), this basic necessity of life (housing) has been kept far from the reach of the low-income earner. In this strive for shelter; stabilized earth is an alternative building material which is comparatively cheaper than conventional building materials used in the construction of houses in urban centers. Due to modernization, earth is now associated to villagers or only used in the construction of historical buildings. It is no doubt that we can use our abundant resources to bridge the housing gap between the high income and the low income earner and give not only shelter but with comfort and providing shelter at an affordable rate to the low income earner. Three case studies were used for the purpose of this research. The findings of the study revealed a 30% reduction in cost of constructing a building with adobe bricks over sandcrete hollow blocks. The research identified and highlighted the cost effectiveness, thermal insulation and the durability of clay (earth). The study concluded that the use of earth should be employed by professionals in the construction industry to increase its acceptability by the public.

Keywords: Stabilized earth; Housing; Construction; Adobe bricks; Nigeria

Introduction

Virtually all developing countries, irrespective of size and level of industrialization, are experiencing rapid urbanization as limited land and resources for cultivation and growing agriculture, populations continue to expel families from agricultural regions into cities and large metropolitan areas. Addressing urban housing crisis is a major challenge for most developing countries due to the increasing cost of building materials, making it very expensive and difficult for a common man to afford [1].

In Nigeria today, the poor and low income group dominate both the rural and urban areas. These groups have been making efforts at provision of housing for themselves [2]. The efforts by these groups have not really been successful due to the high cost of constructional materials. Therefore, affordable alternative building materials can be a breakthrough to the urban housing crisis.

Earth is a universal building material and is one of the oldest known to humanity. In ancient times, the use of earth construction was very prominent, but due to modernization people have ignored the cost effectiveness, durability and the thermal comfort of earth construction (buildings) and see it as a kind of building that is associated with villagers and low income earners. Soil has been, and continues to be, the most widely used building material throughout most developing countries. It is cheap, available in abundance and simple to form into building materials [1-3].

Statement of the Problem

Considering the increase in housing problems faced all over the world due to population growth and the high cost of building being its major cause, the need for measures to combat this phenomenon becomes imperative. These measures as outlined by the United Nations conference include the development of readily available local building materials as the adaptation of building techniques that would be suitable for local conditions [4]. As a result, a lot of interest has been developing towards the use of readily available local building materials such as earth, in recent years, demonstrating this material has the advantage of availability in large quantities in most regions, low cost of excavation, easy workability and fire resistance over other materials used for the same construction [5].

In most developing nations including Nigeria, the major building material is earth (clay). In such countries or settlements, the buildings are characterized by a dilapidated and poor aesthetic look, apart from the structure looking unsafe after a year or two of construction for human habitation [6]. Due to these reasons, earth is gradually giving way to modern building materials that are relatively expensive.

The construction sector in Nigeria is guilty of neglecting the relevance and benefit of some natural building materials like earth and venturing into the use of manmade (expensive) building materials to construct buildings that most masses cannot afford. This is partly due to the lack of knowledge and understanding on how to make earth durable and aesthetically appealing [7].

Aim and Objectives

- To document the use of stabilized earth as a tool to addressing housing crisis in urban centers at a lower cost compared to fabricated materials, thereby stimulating the awareness of the public particularly the mind of the prospective buildings owners about this technology and its inherent advantages as a valuable complimentary method of building construction.
- To determine whether stabilized earth is applicable to all kinds of soil, weather and climate.
- To identify the properties and explore the possibilities of stabilized earth as an ideal building material.
- To suggest architecture that is less dependent on contemporary building materials such as cement, steel and gas, but which will still be oriented towards achieving uniqueness based on value.
- To show that traditional building methods and materials (earth) could be developed with resources to modern knowledge and technology.

Significance of the Study

The study will create awareness on the use of stabilized earth as a cost effective and durable alternative building material and also as a means of addressing housing crisis in urban centers. This research will also elicit information that will guide the government and the general public in the planning and execution of low-cost housing by incorporating the use of indigenous building materials that are readily available.

Literature Review

Earth is one of the oldest architectural materials, dating back 10,000 yrs, with archeological evidence of earth construction found in the earliest cradles of Middle Eastern and Asian civilizations [8]. The Egyptians Greeks and Romans all developed interesting methods of building with earth. Not just for housing and storage but also for ground monolithic structures. Earth is one of the most widely used construction materials in human history and every continent has a heritage of building with earth [8-10]. Today, it is estimated that more than two billion people live in buildings constructed of earth [1]. The history of earth building lacks documentation, because it has not been highly regarded compared to stone and wood. There are cities built of raw earth, such as: Catal Hunyuk in Turkey; Harappa and Mohenjo-Daro in Pakistan; Akhlet-Aton in Egypt; Babylon in Iraq which still exist till date [8].

About 30% of the world's population, or nearly 1,500,000,000 people, live in a home built in unbaked earth. Roughly 50% of the population of developing countries, the majority of rural populations, and at least 20% of urban and suburban populations live in earth homes [2,4].

Earth as a Construction Material

Earth construction refers to the use of earth which is a natural building material in the construction of buildings. It often involves a particular mixture of soil and clay, with other added materials which are known as stabilizers, it is then compacted and allowed to cure. This type of construction is best suited to dry climates, although it can be used in other, rainier climates as well.

The use of earth as a structural material can be dated back to first year of civilization which is believed to have started along the river Nile [1]. The earth today is no longer regarded as a major building material despite the fact that it continues to leave an undeniable and distinctive imprint on the architectural landscapes, both in rural and urban areas of many countries. Earth as a building material is available in abundance around the world, existing in many different compositions that can be processed in diverse of ways [5].

Up to today, earth remains the main building material used by man both in urban and rural areas. Over the passage of time, human activities have constantly affected the built environment, but nevertheless, it has not affected the use of this building material, which is excavated from the ground, molded and used in construction. This phenomenon results from a body of knowledge refined over cost of time which has enabled the construction of simple hut and modest homes [7,8].

Advantages of Earthen Construction

The most obvious advantage of earth construction is the abundance of the raw material (earth). Other advantages of earthen construction include:

- High thermal insulating properties [1].
- High sound insulation properties [1,2].
- No waste generated during construction
- High workability and flexibility [4].
- High fire resistance
- Earth construction is economically beneficial [6].
- It can be achieved using simple tools and less skilled labour
- Suitable for very strong and secured structure
- It balances and improves indoor air humidity and temperature
- Earth walls (loam) absorb pollutants [8].
- Easy to design with high aesthetical value
- Earth construction promotes local culture, heritage, and material [1,2,4].
- Earth is available in abundance in most regions [7].

Constraints of Earthen Construction

In spite of the well-established technology and the good qualities of earth, it also has its limitations at both the public and the private sector level. The constraints are mainly due to:

- The acceptability of the material in view of bias and stigma attached to the material. Otherwise considered to be the kind material used only by poor people living in rural areas.
- The overemphasis in the use of materials like sandcrete blocks to be of higher strength in tendency to adopt a safer pattern of using established materials.
- The lack of demonstration project that will infuse confidence among the people for using the earthen construction technology for housing and buildings.
- The lack of sufficient machinery to be distributed all over the country to prove the capabilities and for training of entrepreneurs and workers for manufacture of stabilized laterite blocks of required quality and specification.
- Its need for high maintenance depending on the type of construction adopted.

Materials and Methods

Data Collection

The data for the research was gotten from two sources; the primary data source and the secondary data source. The primary data was obtained in the field by the researcher. For the purpose of this research, the primary data was collected from the researchers' visits to three (3) building sites located in Jos which were used as case studies. The secondary data however, came from literature review, interviews, desk research, etc.

Types of Earthen Construction

The following are among the more popular types of earthen construction.

i. Adobe blocks
ii. Rammed earth
iii. Compressed earth bricks

i. Adobe (Laterite) Block: Adobe is air/sun dried brick gotten from earth composed of inorganic soil and sand. The soil must have minimum clay content of 10% to create a bond in the soil. Fibers such as straw may also be added to increase the stability of the block as well as binders. An adobe brick is typically 250 to 300mm and weighs between 13 -22kg. Some of the steps that can be taken to protect adobe structures are;

- Placing (building) walls on concrete or stone foundations since earth absorbs moisture.
- Using water-inhibiting additives (water proofing materials).
- Plastering adobe walls with stucco (Figure 1).
- Providing substantial overhangs to reduce the effect of rain on walls.

ii. Rammed earth: Rammed earth involves the compacting of moist soil between rigid forms (form work) to create monolithic earth walls with similar properties as that of adobe walls. The soil for rammed earth construction must have about 30% clay and 70% sand and small gravel. It is critical to ensure that the moisture content of the wall is just right if not there will be physical defects on the wall when the formwork is removed, which will lead to a weak and crumbly wall (Figure 2).

iii. Compressed earth bricks: Compressed earth blocks (CEBs) are a relatively recent technology and combine the nest characteristics of traditional earthen technology and modern brick making process. Earth is poured into moulds and compressed either manually

Figure 1: Picture showing adobe blocks
Source: Researcher's field work

Figure 2: Showing ways of coupling framework for rammed earth structure

or mechanically (motorized). These bricks are moulded in different forms e.g. solid blocks, hollow blocks, interlocking blocks, perforated blocks, etc.

Stabilization of Earth

Earth stabilizers are materials (substances) added to earth to boost its workability. The use of stabilizers such as cement was derived out of a need to improve wet strength and erosion resistance in very exposed walls [1,3]. In many situations, the use of cement and other stabilizers can be avoided by good design and construction appropriate to earth building.

There are a number of requirements that earth should meet to optimize the benefits of stabilization;

- Soil should be free of humus and plant matter, though under certain conditions, plant matter like straw can be added, provided it is dry, with no danger of later deterioration [1].
- Soil should mainly consist of sand and fine gravel, with only sufficient clay for any required cohesive strength and a proportion of silt to act as void filler.

The main categories of binders (stabilizers) used for earth construction are Portland cement, lime, bitumen, natural fibre and chemical solutions such as silicates [2,3,6].

Structural Application of Earth on Building Components

Earth as a building material can be used in a wide variety of ways within construction to form foundations, walls (both load bearing and non-load bearing), floors, roofs and other elements depending on the type and purpose of the building. It can provide good thermal and acoustic insulation and has a particularly good ability to regulate internal air humidity and quality. If properly used, it is a durable and aesthetically appealing building technology. The application of this material in the components is done according to specification and these components include; foundation, floor, wall and roof.

Preparing the earth

First of all, it is necessary to find the right (workable) kind of soil. Sandy, but not all sand (between 50% and 75% is ok) with a mixture of clay as a binding agent [1,2]. You mustn't have too much clay either, or the finished wall will shrink and crack. The first construction step should be the sieving of the soil through a slanted screen of 1" mesh hardware cloth to separate out any big stones, roots, etc. Spread a tarpaulin over the screened dirt to protect it from precipitation (if the soil contains more than 10% moisture it will puddle, not compress) [2]. When you make a ball of earth in your hand it should hold its shape but break and scatter when dropped (Figure 3).

Figure 3: Crushed soil placed into sieve and soil after it has been sieved

Earth as a Contemporary Building Material

Cynics may question the need to reintroduce what they believe to be an inferior building material best left in the past. Earth when used in buildings is recognized as having a number of remarkable characteristic features for the realization of sustainable development. The use of earth has grown rapidly in the developing nations. In countries with no industrialized means, earth remains the main, if not the essential building material for necessary access to development. Earth in modern architecture represents a considerable improvement over traditional earth building technique [9].

Figure 4: Vikas Community on 4 floors (Source: www.aurovilleearthinstitute.com)

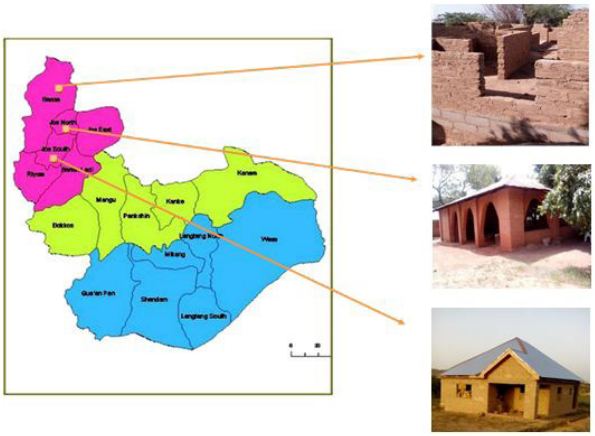

Figure 5: Showing the study area and the 3 selected case studies

The use of earth and its techniques ensure true quality, allowing communities to create their private living environment. Earth has also integrated building structures into a coherent network of self-generated development, which makes use of the most available resources, both natural and manmade (Figure 4 and 5). In modern architecture, with the improvement in technology, earth is used in constructing buildings with multiple floors as seen in Figure 4.

Case Study One

The idea for using earth construction for this building came due to the clients' level of income. The design came as a suggestion for affordable housing. This building came as a medium of addressing urban housing crisis within the Jos metropolis. The adobe blocks that were used for this construction were moulded from the soil excavated on site due to the abundance of this material. The type of stabilizer used for the purpose of this design was the straw which was obtained from an adjacent land where fonio (stem of fonio) was cultivated. The foundation of the building was well treated with waterproofing materials due to the weakness of earth in water proofing (Figure 6 and 7) (Table 1).

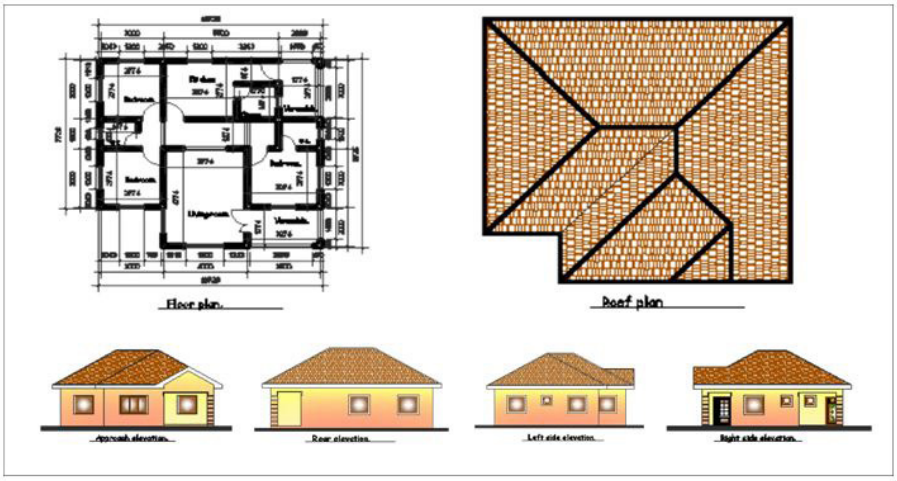

Figure 6: CAD drawings for case study one

Figure 7: Picture showing area where earth was excavated for molding of blocks, the molded blocks and the built house

Building Orientation	Residential Building
Medium of Construction	Earthen construction
Earth Construction Type	Adobe blocks built with sandcrete mortar
Year of Construction	2015
Location	Rantiya, Gyel, Jos South, Plateau State
Client	
Designed By	Tali Janet Oliver
Project Supervisor	Tali Janet Oliver
Number of Floors	One

Table 1: Building Information of case study 1

Case Study Two

Building with earth materials can be a way of helping with sustainable management of the earth's resources (Table 2,3 and 4). This structure is being constructed using sandcrete blocks for foundation walls due to the weakness of earth in water absorption (Figure 8).

Building Orientation	Residential building
Medium of Construction	Earthen construction
Earth Construction Type	Adobe blocks, built with sandcrete mortar
Year of Construction	2016
Location	Bassa LGA, Plateau State
Client	Mr. Mr. daniel
Designed By	Arc. Abi Daniel
Project Supervisor	Arc. Abi Daniel
Number of Floors	One
Number of Apartments	Eleven
Areas of Earth Application	Walls

Table 2: Building information of case study 2

Building Orientation	Historical building (workshop)
Medium of Construction	Earthen construction
Earth Construction Type	Compressed earth bricks built with cement stabilized earth mortar
Year of Construction	1987
Location	The Jos national museum, Jos, Plateau State
Client	The Federal Government of Nigeria
Designed By	Arc. Gideon Bwans
Project Supervisor	Center for Earth Construction Technology (CECTech), Jos museum
Number of Floors	One
Number of Apartments	Three
Areas of Earth Application	Walls, floor and foundation
Purpose of Building	For research, history and earth bricks production

Table 3: Building Information of case study 3

Figure 8: Picture showing columns finished with built cement paste, building at window level, foundation wall with sandcrete blocks and framework of lintel

Case Study Three

The choice of this historical building as a case study was motivated by its durability and natural aesthetical appearance. The building is currently not used for production of compressed earth bricks because of the poor maintenance of production machines. The design is aimed at producing an alternative learning and leisure environment (Figure 9).

Figure 9: Picture showing perspective view of the building and internal view of workshop area

Results

Material	Description	Quantity	Cost (₦)
Cement	50kg	Per bag	1000
Coarse aggregate	$4m^3$	Per truckload	10000
Laterite	$4m^3$	Per truckload	6000
Reinforcement	Y6		800
	Y12		1200
	Y16		1500
Hollow sandcrete block	9 inches	Per unit	160

Table 4: Prices of building materials in Plateau state

Cost Analysis

The cost analysis intended here comprises an appraisal of the cost of raising walls of a room space using the hollow sandcrete blocks and the adobe solid blocks. This is set out to give a comparative price rate for raising the walls of a room space using the two alternative materials (sandcrete solid block and adobe solid block). This analysis is given using the master bedroom of the design of case study 1.

The analysis of the Tables 5 and 6 shows that the walls of the bedroom when built with sandcrete hollow blocks will cost ₦ 88,930.00 while when built with adobe earth bricks will cost ₦ 62,450.00.

Item description	Quantity	Unit	Rate (₦)	Amount (₦)
225mm thick sandcrete block work up to roof level	388	m^2	160	62,080
Concrete work in lintels and overhead beam	-	-	-	15,525
Reinforcement in lintels and ring Beam(rods and stirrup)	4 3.5	M M	1200 550	4800 1925
Formwork and scaffolding	-	-	-	4,875
Total				88,930

Table 5: Showing the brief summary of costing (bill of quantities) for wall built with sandcrete hollow blocks

Item description	Quantity	Unit	Rate (₦)	Amount (₦)
225mm thick sandcrete block work up to roof level	1424	m^2	30	42,720
Concrete work in lintels and overhead beam	-	-	-	8,130
Reinforcement in lintels and ring Beam(rods and stirrup)	4 3.5	M M	1200 550	4800 925
Formwork and scaffolding	-	-	-	4,875
Total				62,450

Table 6: Showing the brief summary of costing (bill of quantities) for Adobe earth blocks wall of super structure 150mm thick

The cost reduction can be depicted in percentage as:

$$= \frac{\text{Grand total (sandcrete blocks)} - \text{Grand total (adobe blocks)} \times 100}{\text{Grand total (sandcrete blocks)}}$$

$$= \frac{88{,}930-62{,}450\times 100}{88{,}930} = 29.776 = 30\%$$

From the calculation above it shows that there is 30% cost reduction when using earth as a construction material over concrete (Table 7).

Characteristics	Clay brick	Concrete block
Moisture absorption	5% to 20%	5% to 7%
Thermal conductivity	Individual solid clay bricks have a lower heat transfer and better insulation than concrete due to its absorption quality.	Higher heat transfer but once they are embedded in mortar and plaster the difference is minimal, especially with hollows filled or as cavity wall.
Appearance	Clay bricks have a natural aesthetic appearance.	Rough surfaces
Render	Clay bricks vary in size and shape considerably and have a smooth surface, rendering is when required.	Require 5mm of render
Cost	Lesser cost of construction	Higher cost of construction
Strength	About 2.9Mpa	About 23.3Mpa

Table 7: Comparison of some characteristics of clay bricks and concrete blocks

Discussion

Building with earth has a great past, but also a promising future. It is definitely an appropriate, cost and energy-efficient, and eco-friendly technology which can promote a sustainable future. Obviously, one has to master the materials and the techniques so as to obtain the optimum possibilities for a harmonious, durable, agreeable and efficient architecture [1,6,8].

Earth as the primary building material has generated interest from the government and other institutions to carry out and support research and experiment, both in the area of application and production [4].

Today, the threat hanging over the ecological balance highlights interest in the materials and techniques that are inherently environmentally friendly [9,10]. The increased involvement of people in the control and management of their living environment results from the awareness of the options available [1,3]. Building with earth emerges as one of the efficient short-term means of

production of housing or public facilities that are both economical and of high quality [7].

The results herein will assist building professionals to know how and where clay can serve as an alternative for any contemporary building material, with the aim of ensuring affordable or low-cost buildings. Results showed a 30% reduction in the cost of constructing the walls of a room space with adobe earth bricks over sandcrete hollow blocks.

The findings of this study will no doubt be of great value to the construction industry in appreciating the uniqueness of earth and judiciously making use of it in the construction of buildings.

Conclusion

The study has revealed the advantages of stabilized earth in the construction of buildings in that it is cheap and readily available. The cost of building is further reduced when the clay is casted in situ thereby eliminating the cost of transportation. Earth structures also have the advantages of being cooler in summer and warmer in winter due to the heat capacity of the material and wall thickness, making artificial air-condition unnecessary. Finally, if earth architecture is adopted based on the findings of this study, the problem of urban housing crisis for most Nigerians could be a thing of the past.

Recommendations

- First and foremost, to obtain maximum utilization of earth, the government of Nigeria should use earth in carrying out her housing scheme.
- The government through its enlightenment programs should let the people know how clay should be prepared to enhance proper construction.
- Manufacture of earth products such as burnt bricks and adobe blocks should be made available to the public and at affordable rates.
- Architects should encourage the use of earth by specifying them in their designs.
- All those that have done any form of research on earth construction should try as much as possible to implement it.
- Professionals in the building industry should also employ the use of earth in their construction projects to increase its acceptability by the public.
- Finally, people should be enlightened about the merits of using clay in the erection of their residential houses in terms of durability, thermal comfort and affordability.

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