AN ASSESSMENT OF THE COMPRESSIVE STRENGTH CHARACTERISTICS OF STRAW STABILIZED EARTH BRICKS FOR LOW COST HOUSING IN NIGER STATE, NIGERIA

BY

ADELAJA ISHOLA HASSAN

2007/1/28611BT

DEPARTMENT OF INDUSTRIAL AND TECHNOLOGY EDUCATION

SCHOOL OF SCIENCE AND SCIENCE EDUCATION

FEDERAL UNIVERSITY OF TECHNOLOGY

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A RESEARCH PROJECT SUBMITTED TO THE DEPARTMENT OF INDUSTRIAL AND TECHNOLOGY EDUCATION SCHOOL OF SCIENCE AND SCIENCE EDUCATION, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

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CERTIFICATION

I ADELAJA ISHOLA HASSAN Matric No 2007/1/28611BT an undergraduate of the department of Industrial and Technology Education certify that the work embodied in this project is original and has not been submitted in part or full for any other diploma to degree of this or any other university.

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Name Signature

APPROVAL PAGE

This project has been read and approved on meeting the requirement for the award of B. Tech degree in Industrial and Technology Education, School of Science and Science Education, Federal University of Technology Minna.

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SUPERVISOR SIGN & DATE

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HEAD OF DEPARTMET SIGN & DATE

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EXTERNAL EXAMINER SIGN & DATE

DEDICATION

This study is dedicated to almighty ALLAH for guiding me through the research and to my parent: Alhaji Tajudeen Obayinka Adelaja and Alhaja Adijat Adelaja and also my lovely sisters and beloved brothers who have given me moral, financial and spiritual support for good successful and qualitative education. I owe a lot of gratitude to them all.

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ABSTRACT

This study was designed to assessed the compressive strength characteristics of straw stabilized bricks for low cost housing in Niger state, Nigeria. Three research questions guided the study. An experiment research design was employed for the study. The study was conducted in Building technology laboratory, Federal university of Technology, Minna, Niger State and Matumbe area of Minna Niger State. The material used for the test was laterite, straw, cement and wooden mould (300 X 150 X150mm). The finding of the study indicated that the compressive strength of mix ratio 1:1:8, 1:1:10, 1:1:12 met the requirement specify by British standard BS 3921, the water absorption of mix ratio 1:1:8, 1:1:10, 1:1:12 range from 19% to 30%. The cost analysis show the amount used in the production of straw bricks of mix ratio 1:1:8, 1:1:10, 1:1:12, for mix ratio 1:1:8 N 1,145 was used to produce 22 bricks, while, 1 unit of 1:1:8 straw brick cost N52, for mix ratio 1:1:10 N 1,205 was used to produce 26 bricks, while 1 unit 1:1:10 straw brick cost N46, for mix ratio 1:1:12 N 1,265 was used to produce 22 bricks, while 1 unit of 1:1:12 straw brick cost N42 . Based on the finding, it was recommended that in construction of low cost housing, straw stabilized bricks should be use for construction, mix ratio of 1:1:12 is recommend for straw bricks, when using straw bricks for construction, sandcrete block should be use for the construction of substructure (foundation) level or it should be damp proof with damp proof membrane material.

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INTRODUCTION

Background of study

Housing is recognized world-wide as one of the basic necessities of life and a prerequisite to survival of man (Salau, 1990). While housing is important to every individual and nation, housing crisis remains one of the global problems and rising challenge facing both urban and rural residents, particularly in most developing countries.

In Nigeria, though housing provision by the government commenced before the country got her political independence from Great Britain on October 1, 1960, the housing problem in Nigeria still remains intractable as many rural and urban populations in the country do not have access to decent, safe, and afford able housing due to high cost and availability of building materials. Building material are materials used for the construction of building structures, such as sandcrete, laterite, glass, straw, timber, plastic, mud or clay, stones, concrete, thatch, fabric, gypcrete, metal, e. t. c. Successive Nigerian governments have paid lip-service to the need for alternative sources of building materials in view of the escalating cost of the conventional or imported ones. In 1991 for instance, the Association of Housing Corporations of Nigeria AHCN, championed the use of locally sourced building materials when in collaboration with the Akwa-Ibom state government and built an estate at Uyo with local materials, but that initiative was not followed up. Similarly, efforts by the Nigerian Building and Roads Research Institute NBRRI to popularise the use of local alternatives to the conventional building materials have met a brick wall, apparently because of our penchant to regard anything locally made as inferior, but with the high cost of land, funds, materials and labour almost making affordable housing a mirage, there is need to look for locally made materials, one of the materials that readily come to mind is straw bricks, could be cost effective especially in building houses for the lower income and vulnerable groups

A straw stabilized brick is a building material produced locally which consist of straw (dry rice tusk) laterite and cement, is significantly economical, technical affordable and sustainable than using conventional block and concrete for building construction. Laterite according to Microsoft Encarta 2009 a reddish mixture of clayey iron and aluminum oxides and hydroxides formed by the weathering of basalt under humid, tropical conditions, has been used as construction materials in every continent and in early age stabilized with straw (chop dry rice tusk or elephant grass) for construction in most ancient countries like Egypt, Israel, Rome and even Nigeria. Bricks are stabilized with cement, lime, bitumen, or straw to improve its properties. The inclusion of this additive (straw, lime, cement, bitumen) is meant to improve the properties of bricks by having control action on contraction, water absorption, expansion and cracking. Flaherty (1980) showed that better product can be archived if laterite is stabilized with cement, lime, straw and bitumen. In Nigeria and other countries, the majority of houses in rural areas are built with laterite (Lasisi and Usunde, 1985), Lateritic soil has some advantages over sandcrete which make it potentially a very good and appropriate material for construction of structures in the developing countries. These advantages include availability of laterite and cheaper to get than sandcrete. Ola (1985) revealed in his study that stabilization of laterite with cement, lime, bitumen, straw e. t. c are efficient means of improving engineering properties of laterite soils. Most recently cement stabilization has received widespread use.

This study aims to assessed the compressive strengths, water absorption rate and costs of production of straw stabilized bricks for low cost housing in Niger state, Nigeria

Statement of the problem

People ignore the advantageous use of straw bricks in building construction in Nigeria. a very great observation is that developers have neglected the use of traditional building materials, most especially locally made bricks which have been in existence long ago and make use of conventional building materials. Nigerian Building and Roads Research Institute NBRRI to popularise the use of local alternatives to the conventional building materials but that initiative was not followed up, this has so much contributed negatively to the economy of the nation at large. Local materials for the production of these bricks are lying waste and unextracted, this has raised the cost of acquisition of building by both government and private sectors.

Base on the foregoing therefore this study is designed to assess the compressive strength properties of straw stabilized bricks for low cost housing in Niger state, Nigeria.

Scope of the study

This study is delimited to the compressive strength, water absorption rate, and cost analysis used in the production of straw stabilized bricks for functional construction of low cost housing in Niger state, Nigeria.

Purpose of the study

The purpose of this study is to assess the properties and cost of straw stabilized earth bricks. Specifically the study will:

1. Find out the compressive strength of straw stabilized bricks.
2. Find out the water absorption rate straw stabilized bricks.
3. Find out the cost in the production of straw stabilized bricks.

Significance of study

This study will encourage government and private investors, middle and low class income earner in provision of housing in Niger state.

Government will be encourage in housing delivery to society if straw bricks is use for construction of building because it cheaper than some conventional building materials, it will also promote private investor in building cost because they will be able to produce more housing than using other building materials such as sandcrete. The middle and low income will also able to own their personal house, because if straw bricks it use, amount use in building construction will be reduce, therefore government and private investor will be able to produced more housing and give it out at cheaper rate to low and middle income earner in Niger state, Nigeria.

Research Question

The following research question, were formulated to guide the study

I. What is the compressive strength of straw stabilized bricks?

II. What is the water absorption rate straw stabilized bricks?

III. What is the cost of production of straw bricks?

CHAPTER II

REVIEW OF RELATED LITERATURE

With regard to this content, the related literature for this study was reviewed under the following

a) Structural performance of straw bricks
b) The concept of low cost Housing
c) Raw materials used in straw bricks making
d) Basic Constituent of Laterite bricks
e) Soil Stabilization
f) Considerations for selecting building materials

Structural performance of straw bricks

Traditionally, lateritic soils, which are reddish brown in colour, have been used as brick for buildings without any cement content. Recently, modern builders started introducing some percentage of additives such cement, manure, straw, lime to stabilize to laterite for moulding bricks.

Straw is an agricultural by-product from wheat, oats, barley, rye, rice and others, they are strong in tension and can be use alone or in a post-and-beam construction, to build straw bale houses. and it also use in the production of bricks to help reduce cracking. According to Oak Ridge National Lab and Forest Product Lab testing straw has moderate insulation characteristics about R-1.5/inch.

Straw bricks are made by mixing laterite and straw and cement with water, placing the mixture into moulds and drying the bricks in the open air for 28days, M. Blondet(1986) stated straw is useful in binding the brick together and allowing the brick to dry evenly. Straw bricks are joined with a mud or cement mortar and can be used to build walls, vaults and domes,

Walker (2005) stated that is no standard testing for straw bricks, most researchers determined the compressive strength using the testing method used for fired clay brick and concrete masonry block such as ASTM 1984, BS 6073-1:1981,BSI 1985, BS EN 772-1, BS 1924-2:1990, Standard Australia 1997, Australian Standard 2733, standard used in this study is BS 3921 and European standard EN 7711.18 which stated that minimum value of compressive strength of bricks is 2.5N/mm^2 at 28days. Water absorption is a function of clay and cement content and usually related with the strength and durability of straw bricks and therefore it is important to determine the rate of water absorption of earth bricks. Oti (2009) stated that water absorption rate decrease with increasing in age of earth bricks. High rate of water absorption of a specimen may cause swelling of stabilized clay fraction and resulting in losing strength with time. As observed by Walker (1997) water absorption, as well as porosity, increases with clay content and decreasing cement content. Between cement, lime, cement-lime and cement-resin, combination cement and resin stabilization show the lowest water absorption both in capillary absorption and total absorption. Freidin and Errel (1995) tried to reduce the water uptake by adding a hydrophobic material, in this case was siloxane-polymethylhydrohen-siloxane and combined with slag + fly ash which is highly absorbent and the result showed that the water uptake with the addition of 0.5% siloxane less than a quarter of the water uptake of fly ash-slag without additive.

Load bearing Straw brick wall construction requires particular attention for good bonding (avoiding continuous vertical joints) and ensuring stability. Straw bricks where is used, the substructure (foundation) should be damp proof with d.p.m materials or construct with sandcrete blocks. A well built straw bricks wall has very good sound insulation properties, excellent fire resistance and high thermal insulation (*Otto Ruskulis 2002)* a typical example of a house built with straw is shown in the appendix

They require very little or no generated or mechanical energy in production and high manufacture time. Straw bricks can be use as lintels for opening in a structure, form arches particularly over small spans (less than a metre), and even domes, although this requires high levels of bricklaying skills as well as more stringent demands from engineering and approvals processes.

Benefit of straw stabilized earth bricks

Straw brick is an ideal building material for low cost housing construction. It is low cost because it utilises the sun for drying, raw materials and labour used are locally abundant and available. The costs savings in locally and manually produced straw bricks are derived from manufacturing and transport costs and sandcrete blocks require high energy in their production, It was observed that the building with laterite brick has the best thermal performance than the others which require mechanical ventilation or cooling in order to maintain the minimum thermal comfort level within the building. Anand (2003).

The Concept of Low Cost Housing

Housing, literally is defined as Buildings or other shelters in which people live, housing represents one of the most basic human needs, Housing as a unit of the environment, it has a profound influence on the health, efficiency, social behavior, satisfaction and general welfare of the community (Onibokun 1998). To most groups housing means shelter but to others it means more as it serves as one of the best indicators of a person's standard of living and his or her place in the society (Nubi, 2008). Architect and construction dictionary by Cyril M. Harris (fourth edition, 2006) define housing as a shelter or dwelling place or a collection of such place, also housing can be define as the means of providing sheltered to the people or group of people in a given community, the definitions shows that provision of housing is very important to human existence and this can only be archived through the construction of low cost housing.

Low cost housing can be defined as housing affordable by people on low incomes. Low cost housing is a term often used for houses that are constructed in such a way that middle and low income people would be able to afford

One of the major housing policy initiatives was the Policy on Affordable Housing that was initiated in 1979 by the Shehu Shagari Administration is ensure all Nigerians own have access to decent housing and accommodation at affordable cost by the year 200OAD. The policy though laudable was unable to meet the nation's housing needs because it was based on the unsustainable tenet that houses will be provided by government (this remains the anomaly that we must resolve). The implementation of the 2002 housing policy reforms was a promising beginning, but a lot remains to be done. All governments in Nigeria since independence highlighted housing as a major priority. Unfortunately for over 52 years of its independence, Nigeria is yet to develop a vibrant mortgage market and houses continue to be provided through the tortuous traditional method of buying land and building over some years, which could be an individual's entire life time. In many cases such buildings are left uncompleted or individuals have to deplete their entire life savings in order to build a home.

In a news report on the Nigerian Housing Sector aired on African Independent Television (AIT), it was stated that between 1973 and 2006, the Federal Housing Authority (FHA) built only 30,000 housing units nationwide. According to Mr. Tunde Ipinmosho of the Federal Housing Authority (FHA), the current housing deficit is about 12 million homes. If we take the current population of 140 million Nigerians as reported by the National Population Commission after last year's census exercise and assume 30 percent of the population as working adults we have 42 million estimated working adults; assuming about 45 percent or 18.9 million of the working adults qualify for mortgage loans, and assume an average house final selling price at about Naira 2.8 million for a 2-bedroom flat, the possible size of the mortgage market is close to Naira 53 trillion. Looking at the statistics we see that there are tremendous opportunities in the Nigerian housing sector waiting to be tapped. We should note that the government alone cannot fill the housing gap.

In order to fill the gap we would have to leverage on the resources available in the private sector, while also encouraging foreign investment (in short government has no business building houses). Government (federal and the sub-national governments) should focus on providing a favourable investment climate, infrastructure, and mortgage insurance to first time home buyers and low-to middle income families. We must however, note that there are challenges to harnessing the huge potentials inherent in Nigeria’s housing sector, and invariably providing affordable housing in Nigeria.

In proffering affordable housing solution to your needs, important factors as to bear in mind in such as:

Building Design: The first aspect you must consider in owning affordable housing is the building design. The design of an apartment or house impact greatly on construction cost and for a building to become affordable, spaces must be reduced to living, dining, room(s), convenience(s) and kitchen. Even after reducing what is provided for no sheer essentials, there sizes also must be just appropriate because the bigger a house or an apartment the more the cost of construction. For example, an affordable 3 bedroom apartment or house should not be occupying more than 100sqm, anything above this will have left the region of low building.

Finance: The second factor in proffering quality affordable housing solution is the aspect of finance. The access to mortgage provisions helps affordability a great deal especially when the cost and tenure of finance are very competitive. The interest rate/charges payable on a mortgage and the tenure of the loan are critical elements of affordability, the lower the rate and the longer the tenure, the more affordable the house type because it means more people will be able to take and repay such loans based on their current earning since constitutionally, individuals are not allowed to spend more than about 30% of their earnings on housing.

Building Materials: Finally, in devising strategy to owning low income apartments, you must consider building material types and finishing. For example, there are more affordable materials apart from the regularly used sandcrete blocks like laterite blocks which require lesser amount of cement to stabilize and finish.

It has also been proved to be better suited for our tropical climate. It is estimated that one can save between 30-40% of the building cost when laterite is used as against regular sandcrete block.

Raw materials used in straw bricks making

Input materials for bricks for straw bricks making include laterite, cement and straw.

Laterite: is a reddish mixture of clayey iron and aluminum oxides and hydroxides formed by the weathering of basalt under humid, tropical conditions. . Laterite is mined while it is below the water table, so it is wet and soft (Richard. A 2010), Upon exposure to air it gradually hardens as the moisture between the flat clay particles evaporates and the larger iron salts lock into a rigid lattice structure and become resistant to atmospheric conditions. The art of quarrying laterite material into masonry is suspected to have been introduced from the Indian subcontinent. David (May 2009)

Cement: is a binder, a substance that sets and hardens independently, and can bind other materials together. Cement should always be stored in dry place, off the floor and should be use within three months of the date of manufacture. Never use cement that has lumps in it and only use cement from a well known brand that has an SABS mark of approval on it.

Water: is one of the most important elements in construction but people still ignore quality aspect of this element. The water is required for preparation of mortar, mixing of cement concrete and for curing work etc during construction work. The quality and quantity of water has much effect on the strength of mortar and cement concrete in construction work. Only clean clear potable water should be used in the manufacture of the blocks and bricks. Any organic material in water will prevent the cement from setting. Chemicals and impurities could also affect the strength of the end product. There should be enough water for the, a during brick production. the water needed for brick production can take away from the other uses of water, such as drinking and cooking, washing, livestock watering and other domestic uses. It takes approximately 600L of water to produce 1000 bricks (Anne Beamish/Will Donovan 1993).

Straw: Straw is an agricultural by-product from wheat, oats, barley, rye, rice and others, they are strong in tension and can be use alone or in a post-and-beam construction, to build straw bale houses and it also use in the production of bricks to help reduce cracking

Basic Constituent of Laterite bricks

A lot of definitions have been given to laterite depending on the professional inclination of the authors while some are purely morphological, some are purely physical and some others are purely chemical. Laterite is well known in Asian countries as a building material for more than 1000 years. It was excavated from the soil and cut in form of large blocks; temples at Angkor are famous examples for this early use. At begin of the 19.century it obtained scientific interest when the English surgeon Francis Buchanan (1807) travelled along the western coast of southern India and published his manifold observations and results. He coined the term laterite when he wrote (1807): "What I have called indurated clay …is one of the most valuable materials for building, usually it is use in the production of bricks

Bricks are one of the oldest known building materials dating back to 7000BC where they were first found in southern Turkey and around Jericho. The first bricks were sun dried mud bricks. Fired bricks were found to be more resistant to harsher weather conditions, which made them a much more reliable brick for use in permanent buildings, where mud bricks would not have been sufficient. Fired brick were also useful for absorbing any heat generated throughout the day, then releasing it at night. Man has used brick for building purposes for thousands of years. Archaeological excavations have unearthed a brick that authorities dated as 9,000 to 10,000 years old; this brick was discovered at the site of an ancient settlement beneath the city of Jericho.

The earliest bricks, made in areas with warm climates, were simply placed in the sunlight for hardening. Sun-dried bricks, which were used extensively in ancient times, especially in Egypt, were made of clay mixed with straw. Early in civilization, bricks were baked by using a fuel; these bricks were made of clay mixed with straw to give them added strength during drying and baking in crude ovens.

The Bible contains the earliest written record of the production of bricks, which were made by the Israelites under their Egyptian taskmasters (Exodus 1:14; 5:4-19). The Bible also records that burnt brick was used in building the Tower of Babel (Genesis 11). The Greek historian Herodotus, in the 5th century B.C., stated that burnt brick was used in building the wall of the city of Babylon. In addition to the Egyptians, the ancient Assyrians, Chinese, and Romans also used brick. In China, brick was used to build several parts of the Great Wall, which dates from the 3rd century B.C.

Modern Brick Production; Bricks were made by hand until about 1885. With the introduction of brick making machinery, the number of clays that could be made into brick was greatly increased and so was production capacity. Handmade brick was produced at rates ranging up to 36,000 bricks per week; by 1925 a brick making machine produced 12,000 bricks per day.

In the United States, the brick industry reached a peak of production in the early 1900's, when more than 10 billion bricks were produced annually. In later years, there was a significant decrease in their use; in 1939 less than 5 billion bricks were produced. Since then, production has climbed to about 10 billion bricks a year. Much of the resurgence of the brick industry in the United States, a major world producer, has been attributed to the vast home-building programs. About 60% of brick production is used in residential construction.

Types of bricks

The various available types of bricks may be classified by colour, mechanical strength and the purpose for which they are intended according to Hamilton, (1978).

Common Bricks: Used in building where their appearance is of little or no consequence. It may vary in colour from red to pale yellow. They are not vitrified and normally not fired higher than 1830^0F (1000^0C). They are not expected to have a great compressive strength.

Facing Bricks: These are more carefully made and the quality of the raw materials is vigorously controlled. They are sometimes fired beyond 1000^0C to produce a more acceptable surface and this is accompanied by greater mechanical strength. They are mostly used on approach elevations, entrance porches and specific areas to captivate the attention of the observer.

Engineering Bricks: These are strong type of bricks which are fired to the point of vitrification or a temperature approaching this state under reduction condition which achieves maximum strength without deformation. Such bricks have very great compressive strength and the production is carefully controlled.

ASTM standard categorized brick as building brick

Table 1

Bricks Name	**ASTM standard**
building brick	ASTM C 62
facing brick	ASTM C 216
hollow brick	ASTM C 652
thin veneer brick	ASTM C 1088
Pedestrian and Light Traffic Paving Brick	ASTM C 902
Heavy Vehicular Paving Brick	ASTM C 1272
Glazed Brick, Single Fired	ASTM C 1405
Firebox Brick	ASTM C 1261
Chemical-Resistant Masonry Units	ASTM C 279
Sewer and Manhole Brick	ASTM C 32
Industrial Floor Brick	ASTM C 410

Properties of bricks

Compressive strength: This is a property of bricks which can be determined accurately. The compressive strength of bricks is found by crushing 12 of them individually until they fail or crumble. The pressure required to crush them is noted and the average compressive strength of the brick is stated as Newton's per mm of surface area required to ultimately crush the brick. The crushing resistance varies from about 3.5 N/mm2 for soft facing bricks up to 140 N/mm2 for engineering bricks. The bearing strength of a brick wall 215 mm thick is very much greater than the loads a wall will usually carry. .

The average compressive strength of some bricks commonly used is:

- Mild (i.e. soft) stocks 3.5N/mm2
- 2nd Hard stocks 17.5 N/mm2
- Flettons 21 N/mm2
- South water A 70 N/mm2

Water Absorption: The amount of water a brick will absorb is a guide to its density and therefore its strength in resisting crushing, according to procedure laid down in water ratio absorption the average water absorption of common bricks should not be more the average 25% by weight after immersion in water for 24hrs

Hardness: is a somewhat vague term commonly used in the description of bricks. By general agreement it is recognised that a brick which is to have a moderately good compressive strength, reasonable resistance to saturation by rainwater and sufficient resistance to the disruptive action of frost should be hard burned.

Frost resistance: if bricks are saturated and water within their freezes (expanding as it freezes up to -4c) it is likely that small cracks will develop causing face of the bricks to break away, care is required in exposed areas e.g Parapet walls, chimney stacks and garden walls should be built of sound, hard burned bricks protected with coping, cappings and damp-proof courses.

Efflorescence: Clay bricks contain soluble salts that migrate, in solution in water, to the surface of brickwork as water evaporates to outside air. These salts will collect on the face of brickwork as an efflorescence (flowering) of white crystals that appear in irregular, unsightly patches. This efflorescence of white salts is most pronounced in parapet walls, chimneys and below dpcs where brickwork is most liable to saturation. The concentration of salts depends on the soluble salt content of the bricks and the degree and persistence of saturation of brickwork.

Efflorescence may also be caused by absorption of soluble salts from a cement rich mortar or from the ground, There is no way of preventing the absorption of soluble salts from the ground by brickwork below the horizontal dpc level, although the effect can be reduced considerably by the use of dense bricks below the dpc.

Sulphate attack on mortars and renderings: When brickwork is persistently wet, as in foundations, retaining walls, parapets and chimneys, sulphates in bricks and mortar may in time crystallise and expand and cause mortar and renderings to disintegrate. To minimise this effect bricks with low sulphate content should be used.

Soil Stabilization

The soil stabilization means the improvement of stability or bearing power of the soil by the use of controlled compaction, proportioning and/or the addition of suitable admixture or stabilizers. It a techniques to enhance the natural durability and strength of a soil and practiced in many countries. Soil stabilisation has been used widely since the 1920s mainly for road construction. When a soil is successfully stabilised the following effects will be evident.

1. strength and cohesion of the soil will increase,
2. permeability of the soil will be reduced,
3. the soil will be made water repellent,
4. the durability of the soil will increase,

5. The soil will shrink and expand less in dry and wet conditions.

Many stabilisers have been tried, including manufactured ones such as Portland cement, lime, bitumen, gypsum, alkalis, sodium chloride, calcium chloride, aluminium compounds, silicates, resins, ammonium compounds, polymers, and agricultural and industrial wastes. The most widely used stabilisers in developing countries are Portland cement, lime, bitumen, Manure and Straw, but straw and manure are usually use in rural areas or suburbs or a region.

Raw earth can be stabilised in a number of different ways. (Houben & Guillaud, 1994) suggests that there are six different mechanisms for soil stabilisation, namely: raising density, reinforcement, linking, binding, waterproofing and water repellent treatment. Some of the major stabilisation techniques are; Mechanical stabilisation, Portland Cement Stabilisation, Lime stabilisation, Bitumen stabilisation and Straw stabilisation

Mechanical stabilisation: Mechanical stabilisation is the process of mixing two or more soils to obtain a desired particle size distribution and/or reduce plasticity. Examples would be the addition of a sandy material to a clayey material, or the addition of a fine material (usually of low plasticity) to a coarse material which is deficient in fines. Theoretically any soils can be mixed to improve quality. In practice, however, the process is best reserved for those materials having low plasticity indices or which are non-plastic. Thorough mixing of materials is important and it is very difficult to adequately mix plastic materials (e.g. heavy clays), the optimum proportions for mixing are determined from laboratory tests.

Portland cement stabilisation: Portland cement is a mechanical additive that can be used for soil modification (to improve soil quality) or soil stabilization (to convert the soil to a solid cement mass). The amount of cement used will dictate whether modification or stabilization has occurred. Nearly all types of soil can benefit from the strength gained by cement stabilization. The amount of cement required is determined by laboratory testing, usually using the unconfined compressive strength test.

Construction practices significantly effect the subsequent performance of cement stabilised materials, and each of the following aspects must be closely controlled: pulverisation,cement content, moisture content, mixing, compaction, finishing and Curing.

Rapid compaction after mixing is possibly most important as cement hydrates relatively quickly.

Lime stabilisation: When hydrated lime (or quick lime) is added to a soil in the presence of moisture a series of reactions is set in motion. The actual physical and chemical processes which occurs are quite complex. The reaction between lime and soil can be considered in three major, overlapping stages:

i. agglomeration of fine clay particles, though base exchange;
ii. weak cementing action, due to calcium carbonate formation; and
iii. slow, long-term cementing action.

The reaction of lime with soil depends on the type of clay minerals present in the soil. For the reaction to be effective the soil must contain kaolinite or montmorillonite minerals. If the clay minerals are illite or chlorite, a pozzolan must be added to produce the desired effects. The normal pozzolan which is used is fly ash. Small amounts of lime (1% to 3%) may reduce the soil plasticity and this process is referred to as lime modification. The more normal process is the addition of 3% to 6% lime, although there is now a school of thought which suggests the process is more effective with fairly high lime contents (in the order of 10%).Mix design is based on the selection of the lime content necessary to provide required strength and durability. Lime contents may be determined by strength tests (e.g. CBR), or by Atterberg Limits, or by pH values.

Bitumen stabilisation: The addition of a bituminous material to soil or crushed rock material is intended to either provide a cohesive binder for non-plastic materials, or to waterproof a cohesive material. Bituminous binders which have been used for stabilisation work include bitumen, cut-back bitumen, bitumen emulsion and tars. Construction processes are similar to those used for cement stabilisation. Adequate pulverization of the soil to be stabilised is very important, and this may be facilitated by partially pulverising, adding portion of the lime, repulverising and then adding the balance of the lime.

Straw stabilisation: This is the oldest method of stabilizing brick which is natural stabilization method, the Israelites made bricks from a clay dug from the earth mixed with straw and baked in crude oven or burned in a fire. Straw earth bricks are made from a mixture of earth, plenty of chopped straw or hemp or grass which act as a structural binders to prevent cracking. The molded brick is then left out in the sun for several weeks to dry. This sun drying process improves the strength and durability of the bricks and makes them less susceptible to cracking under loads.

Consideration for selecting building materials

Every building project involves the choice of building materials or means used for the selection process. As with the design process, cautious consideration of contextual preconditions is crucial to selecting appropriate building materials or products. In addition, selecting suitable building material options can be a very complex process, being influenced and determined by numerous preconditions, decisions, and considerations. In other words, in choosing the right material, there is not always a single definite criterion of selection, which means designers or architects have to take into account a large number of material selection factors. Therefore, the available information or data on building material and product options must be constantly evaluated to make well-considered and justifiable material choices, during the design-decision making and selection processes.

The starting point for any house design is the selection of “appropriate materials”, where availability plays an important role (Stulz & Mukerji, 1981). "Appropriate" building materials should consider resource level, durability, reparability and recyclability during the service lifetime. Service life can be defined as aesthetic, economic, functional, physical (use and maintenance) and technical performance (KTH & NTNU, 1998, Melby)

Important factors to bear in mind in the selection of such materials are:

• Availability: Availability of materials is very important when choosing materials, raw materials use in building materials make a certain building materials not be readily available i.e. clay use in bricks production is readily available but sand use in sandcrete use in blocks is from river bed which is not readily available, sometime building materials have to be imported i.e. floor/wall tiles mostly imported from china, a material such as timber which is readily available can also be use as flooring materials. such as time of manufacture of the materials and delivery

•Construction: Level of skill and/or knowledge construction of some building materials requires high skills, materials such as galas and timber require hidg skill of construction than sandcrete block, also construction time of a materials also should be bear in mind when selecting building materials, i.e. craftman laying block will be fast in laying than craftman laying bricks because bricks is smaller in size and heavier than blocks. Likewise craftman constructing with glass or metal will be slower than that or bricks because glass is a delicate material and it as to be handle with care which the construction work to be slow while some metals are heavier and require some welding process to fix

•Economical Factors: Cost is one of important to bear in mind when selecting building materials, cost of building materials is a major factor affecting provision of housing in developing countries the using of local materials such as make a great economic impact in provision of housing in developing countries i.e. a straw bricks house is cheaper than a sandcrete house and performance the same functional behavior and good appearance like or more than sandcrete block if a quality materials is use during production. Others economical factors are transport price of materials to construction site and also workmanship of craftman to fix the materials.

• Environment/ Social Factor: Amount of energy consumption during manufacture of such building materials should be put into consideration, effect of enviorment on the materials should also be bear I mind when selecting building materials i.e. straw brick cannot be produce and using in construction during raining season, because the straw use during the production can be dry, and the bricks as to be sun dried, unlike like sandcrete block in raining season the raw materials is available and it require little amount of heat to dry, although sandcrete blocks as environmental advantage over sandcrete block such as high thermal mass. Social factor include acceptance of materials by the authorities, some materials are not meant to be use in some geographical area

As far as it is practically possible, the final goal of providing "adequate housing" must prevail over distorting factors that can adversely impact on the quality of materials and final outcome of the dwellings. The selection of the materials will result in social, economical and environmental consequences through time.

CHAPTER III

MATERIALS AND METHODS

This chapter review research design, area of study, selection materials, production of straw bricks, analysis of properties of straw bricks and cost analysis.

Research design

The design adopted for this research work is an experimental study as it involves carrying out an experimental research on compressive strength test, water absorption test, and the cost analysis of straw stabilized bricks for low cost housing in Niger state, Nigeria.

Area of study

This study was carried out at Building Departmental Laboratory in Federal University of Technology, Minna, Niger State and Matumbe area Minna, Niger state, Nigeria.

Selection of materials

The materials used for this study are cement, laterite, straw, water, wooden mould (300 x 150 x 150mm).

Cement: The cement used was Ordinary Portland Cement (OPC) bought from a cement depot at Bosso road Minna, Nigeria.

Laterite: The laterite use is obtained from borrow pit at Federal university of technology, Minna Niger State

Water: Tap water was used for the mixing and it was properly examined to ensure that it was clean, free from contaminants either dissolved or in suspension and good for drinking.

Straw: dry rice husk collected from Matumbe area, Minna Niger State.

Production of straw stabilized earth bricks

The production of straw stabilized bricks were made and tested under the following procedure

Tools and Equipment used

- Shove
- 300x150x150 (6inch) Wooden Mould
- Head pan

Batching brick materials

The materials use in the production of bricks is straw, cement and laterite and was batched as follows:

Table 2 Batching of the materials for productivity for straw bricks materials

Straw	Cement	Laterite
1	1	8
1	1	10
1	1	12

Application of water as appropriate using drop test to determine optimum qualities of water

Drop test- This techniques were use to measure the durability and water content of material by subjecting it to a free fall from a predetermine height. A hand full of laterite earth soil which is wet enough to form a ball and squeeze it in hand but not so tight that the water is squeezed out, then the ball was drop from about one metre height into ground, if it breaks up partially then the quality is good, but if it break up completely , there is need to add more water to the mix, this test help to determine the optimum water for the production of brick for a given ratio

Processes

The laterite will be soak for 24hours after 24hours mixing of brick materials was carried out by the addition of well chopped straw(dry rice tusk), cement, laterite in mix ratio 1:1:8, 1:1:10, 1:1:12 and water in appropriate as mentioned in above batching, procedure were carried out to produce a total of 22 bricks with 1:1:8 with a manual wooden mould (300 x 150 x150mm), the same process was repeated for 1:1:10 which produce 26 bricks and 1:1:12 which produce 30 bricks and sun dried. The bricks are cured under room temperature for 7, 14, 21 and 28 days. The curing of bricks is to maintain a satisfactory temperature and humidity regime in brick.

Analysis of properties of bricks

Compressive strength test- The Compressive strength test of bricks and blocks were carried out at the workshop of Building Department, Federal University of Technology, Minna , An electrically operated Seidner compression machine was used for the compressive strength test on the bricks in accordance *with BS 1881 Part 116,* at the curing ages of 7, 14, 21 and 28 days. Three bricks were picked randomly and crushed in each day for each mix of both materials respectively and the average compressive strength was measured. According to standard BS 3921, the minimum value of compressive strength of bricks is 2.5N/mm^2 at 28days.

$$\text{Compressive strength} = \frac{\text{load to failure}(KN/m^2)}{\text{Net area of straw brick}}$$

Straw brick volume = 300mm x 150 x 150mm

Therefore Net area of straw brick = 300 x 150 = 45000

Apparatus

Electrically operated seidner compression machine.

The result of compressive strength straw bricks and sandcrete blocks is given in chapter Four (4). The cursing of brick and block is shown in appendix

Water Absorption Test- Absorption of a brick is expressed as a percentage, and defined as the ratio of the weight of water that is taken up into its body divided by the dry weight of the unit.

Procedure

1. Dry the brick in a ventilated oven at a temperature of 105 °C to 115°C till it attains substantially constant mass.
2. Cool the brick to room temperature and obtain its dry weight (M_1) specimen too warm to touch shall not be used for this purpose.
3. Immerse completely dried brick in clean water at a temperature of 27+2°C for 24 hours.
4. Remove the brick and wipe out any traces of water with damp cloth and weigh the brick after it has been removed from water to obtain wet weight (M^2).

Calculation

Water absorption, % by mass, after 24 hours immersion in cold water in given by the formula,

The average of result shall be reported in Chapter Four (4)

$$W = \frac{M_2 - M_1}{M_1} X\ 100$$

W = Water absorption rate

M_1 = Dry weight

M_2 = Wet weight

The result is given in chapter four(4).

Particle size distribution**-** 500g of sample was measured and soaked in an evaporating dish for 24hours, the soaked sample was wet sieved through the 2mm and 75mm sieves and washed thoroughly until clean water was seen beneath the 75mm sieve. The water that was passed through the sieve was collected into a 1000ml cylinder. The water contain clay particles present in the soil sample so care was taken not to loose any of it.

The particles retained on the sieve were carefully transferred into tray, by using water, the water was removed by decanting and oven drying. The oven dried grains were weighed, then the sieves were cleaned and weighed, then stacked in incrasing order from the smallest mesh at the bottom; 5.00mm, 2.00mm, 3.35mm, 1.18mm, 850mm, 600mm, 425mm, 300mm, 150mm,75mm, and base pan.

The sample was sieved through the stack by using the mechanical sieve shaker for about ten minutes, then each sieve and the sample retained on it was weighed and the percentage of sample retained on each sieve was calculated from:

$$\frac{\text{Weight of soil retained}}{\text{Total weight of sample}} \times 100$$

Percentage passing = 100 – Percentage retained

Cost Analysis

Cost of material used in production of straw bricks is calculated and analyzed.

Analysis of result

The detailed result obtained from cost analysis and test carried out i.e. compressive strength test, water absorption test and cost analysis was presented, analyzed and interpreted in chapter four.

CHAPTER FOUR

PRESENTATION AND ANALYSIS OF DATA

The presentation of detailed result from the test conducted i.e. compressive strength, drop test density test and water absorption test were presented as follows;

Table 4: Number of straw bricks produced:

Ratio	Number of bricks produced
1:1:8	22
1:1:10	26
1:1:12	30

RESEARCH QUESTION I

What is the compressive strength of straw stabilized bricks?

Table 5 show the ratio, curing days, average weight, crushing load for each sample (SP1, SP2, SP3) and average crushing load

SP1 = Sample 1 of straw bricks crushed

SP2 = Sample 2 of straw bricks crushed

SP3 = Sample 3 of straw bricks crushed

Table 5: Crushing load strength (KN) of Straw stabilized bricks

Ratio	*Crushing load (KN)*					
	Curing Days	*SP 1(KN)*	*SP 2(KN)*	*SP 3(KN)*	*Average weight (g)*	*Crushing load Average (KN)*
1:1:8	7TH	48.0	52.2	41.6	19316.1	47.3
	14TH	76.4	76.0	77.7	18992.7	76.7
	21ST	100.3	101.0	98.6	18114.0	99.9
	28TH	152.5	155.4	154.0	17729.0	153.9
1:1:10	7TH	41.6	40.2	44.6	18990.2	42.1
	14TH	67.2	64.8	59.0	18202.8	63.7
	21ST	89.0	92.4	86.1	17820.1	89.1
	28TH	123.6	128.3	121.1	17002.9	124.3
1:1:12	7TH	40.5	36.5	37.5	17700.6	38.2
	14TH	58.9	60.4	57.0	16993.9	58.7
	21ST	85.3	85.0	88.0	16089.1	86.1
	28TH	124.0	122.2	117.6	15992.1	121.2

Table 6 shows the compressive strength of straw stabilized bricks the formula below is used to calculate the compressive strength;

$$\text{Compressive strength} = \frac{\text{load to failure}(KN/m^2)}{\text{Net area of straw brick}}$$

Table 6: Compressive strength of Straw stabilized brick

Ratio	*Compressive strength*			
	7^{th} (N/mm^2)	*14^{th} (N/mm^2)*	*21^{st} (N/mm^2)*	*28^{th} (N/mm^2)*
1:1:8	1.05	1.70	2..22	3.42
1:1:10	0.94	1.41	1.98	2.76
1:1:12	0.85	1.30	1.91	2.69

According to British standard BS 3921, the minimum value of compressive strength of bricks is $2.5N/mm^2$ at 28days. From the result analyzed in table 5, 6 it show clearly that as curing days increase the compressive strength of the bricks increase and the strength is greater than the minimum value stipulated by BS 3921.

RESEARCH QUESTION II

What is the water absorption rate straw stabilized bricks?

Using this formula the below result was result was obtain for water absorption rate for straw bricks

$$W = \frac{M_2 - M_1}{M_1} X\ 100$$

W = Water absorption rate

M_1 = Dry weight

M_2 = Wet weight

Table 7: Water absorption rate for straw bricks after 28 days

Ratio	Dry weight(M_1)g	Wet weight(M_2)g	Water absorption rate (%)
1:1:8	17981.6	21470.0	19.4
1:1:10	16628.2	20535.8	23.5
1:1:12	16771.3	21752.4	29.7

Particle size distribution

Table 12: **Particle size distribution for laterite sand** (total mass of sample used = 500g)

Sieve sizes (mm)	**Cumulative % mass of sample retained (%)**	**% passing**
5.000	0.040	99.96
3.350	0.100	99.90
2.000	0.240	99.76
1.180	1.480	98.52
0.850	2.680	97.32
0.600	5.120	94.88
0.425	10.18	89.82
0.300	15.24	84.76
0.150	25.54	74.46
0.075	29.06	70.94
PAN	99.38	0.620

RESEARCH QUESTION III

What is the unit cost of production of straw bricks?

Cost for mix ratio 1:1:8 (that is, one part of ordinary Portland cement: one part of straw (rice husk): eight parts of laterite) is given as;

8 head pans of laterite @ N 30 = N 240

25kg of cement($^1/_2$ bag of cement) @ N 900 = N 900

1 head pan of Straw @ N 5 =N 5

Total = N 1,145

Total amount of bricks produce with N 1,145 = 22 bricks.

Cost of materials for producing 1 unit of 300 X 150mm straw brick =N52

Cost for mix ratio 1:1:10 (that is, one part of ordinary Portland cement: one part of straw (rice husk): ten parts of laterite) is given as

10 head pans of laterite @ N 30 = N 300

25kg of cement($^1/_2$ bag of cement) @ N 900 = N 900

1 head pan of Straw @ N 5 =N 5

Total = N 1,205

Total amount of bricks produce with N 1,205 = 26 bricks.

Cost of materials for producing 1 unit of 300 X 150mm straw brick =N 46

Cost for mix ratio 1:1:12 (that is, one part of ordinary Portland cement: one part of straw (rice husk): twelve parts of laterite) is given as

12 head pans of laterite @ N 30 = N 360

25kg of cement($^1/_2$ bag of cement) @ N 900 = N 900

1 head pan of Straw @ N 5 =N 5

Total = N 1,265

Total amount of bricks produce with N 1,265 = 30 bricks.

Cost of materials for producing 1 unit of 300 X 150mm straw brick =N 42

Findings

This section presents the findings of the study. The presentations of the findings are with regards to the research questions which are as follows;

1. Findings related to the compressive strength of straw bricks with mix proportion of 1:1:8 1:1:10 and 1:1:12.
    i. The compressive strength of straw bricks are on table 5, the value obtained on the strength test performed for mix proportion 1:1:8, 1:1:10, 1:1:12 meet the requirement specify by British standard BS 3921 at 28days
2. Findings related to water absorption rate straw stabilized bricks
    i. The water absorption rate for straw bricks are on table 7 , the the value obtained on the water absorption test performed for mix proportion 1:1:8, 1:1:10, 1:1:12 range from 19% to 30%
3. Findings related to the unit cost of production of straw bricks
    i. For mix ratio 1:1:8 N 1,145 was used to produce 22 bricks, therefore 1 unit cost N52
    ii. For mix ratio 1:1:10 N 1,205 was used to produce 26 bricks, therefore 1 unit cost N46
    iii. For mix ratio 1:1:12 N 1,265 was used to produce 22 bricks, therefore 1 unit cost N42

Discussion of findings

This study produce 22 bricks with mix ratio 1:1:8, 26 bricks with mix ratio 1:1:10 and 30 bricks with mix ratio 1:1:12. The bricks are cured and crushed with compressive machine to obtain the crushing load (table 5), the compressive strength was calculated and at the end of 28 days, all bricks produce from mix ratio 1:1:8, 1:1:10, 1:1:12, meet the requirement specify by British standard BS 3921 which is 2.5N/mm^2, from the result obtained it shows that the strength of the straw bricks increase as the curing age increase. The water absorption rate test show that mix ratio 1:1:8 as 19.4% absorption rate, 1:1:10 as 23.5% absorption rate, 1:1:12 as 29.7% absorption rate respectively. The cost analysis show the amount used in the production of straw bricks of mix ratio 1:1:8, 1:1:10, 1:1:12, for mix ratio 1:1:8 N 1,145 was used to produce 22 bricks, while, 1 unit of 1:1:8 straw brick cost N52, for mix ratio 1:1:10 N 1,205 was used to produce 26 bricks, while 1 unit 1:1:10 straw brick cost N46, for mix ratio 1:1:12 N 1,265 was used to produce 22 bricks, while 1 unit of 1:1:12 straw brick cost N42 respectively.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the summary of the study, the implication of the study, conclusion and recommendations.

Summary of the study

This study investigates the strength of straw stabilized bricks for low cost housing in Niger state Nigeria.

Chapter one give brief introduction of housing in Nigeria and lack of provision of housing due to high cost of building materials and the scope of the study, statement of problem, purpose of the study and the research question.

Chapter two reviews the following:

a) Structural performance of Straw bricks
b) The Concept of Low Cost Housing
c) Raw materials used in straw bricks making
d) Basic Constituent of Laterite bricks
e) Soil Stabilization
f) Considerations for selecting building in materials

Chapter III involves the research design, area of study, selection materials, production of straw bricks, analysis of properties of straw bricks and cost analysis, that led to the collection and analysis of result in chapter four,

Chapter IV gives the detailed result obtained from cost analysis and test carried out i.e. compressive strength and water absorption test and was presented, analyzed and interpreted.

Chapter V gives the summary of the study, implication of the study, conclusion recommendation, suggestion for further work, the references and appendix of the study.

Implication of the study

The findings of this study have a far reaching implication in the use of straw bricks as an alternative to sandcrete blocks because it can be obtained in a cheaper rate.

Straw bricks can be use in solving the problem of affordable housing if Niger state governments and private sectors in Niger state can embrace the use of local materials and encouraging research on local materials .The basic (laterite) materials use in producing straw bricks is locally available and easier to get than sandcrete use in producing sandcrete block, straw bricks as more advantage over sandcrete block such as, can be locally made, thermal efficiency, financial and strength viability, although the level of skills, time required in laying straw bricks is more than that of sandcrete block and as high water absorption rate than sandcrete block.

Conclusion

After the test and the assessment of straw bricks for low cost housing in Nigeria, the following conclusion was drawn:

1. Straw brick meet the minimum requirement specify by British Standard BS 3921

2. Straw bricks has high water absorption rate

3. The cost of production of straw bricks is cheaper

Recommendation

From the research carried out to assess the strength properties characteristics of straw bricks for low cost housing in Niger state, Nigeria the following are recommended:

1. In construction of low cost housing, straw stabilized bricks should be use for construction.
2. Mix ratio of 1:1:12 is recommend for straw bricks because it produce more bricks than other ratio and it exceed the minimum requirements in terms of compressive strength.
3. When using straw bricks for construction, sandcrete block should be use for the construction of substructure (foundation) level.

Suggestion for further studies

The following are suggested for further study:

1. Mix ratio of 1:1:15 should be carried out and check if it reaches minimum requirement for compressive and produces more bricks
2. Comparative study of the viability of sandcrete blocks and straw bricks for low cost housing
3. More cement ratio should be used to check if the water absorption rate will reduce.
4. Comparative study of strength properties of mechanical press bricks and machine mould sandcrete blocks

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APPENDIX

A Typical House built with straw bricks in Matumbe area of Minna, Niger State, Nigeria

Curing process

Crushing Machine with straw brick

Crushing process