COMPARATIVE EFFECTS OF THE CHARACTERISTIC PROPERTIES OF COMPRESSED LATERITE EARTH BRICK STABILIZED WITH PALM LEAF ASH AND PALM KERNEL FIBRE

BY

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M.Tech/SSTE/2018/8202

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQIUREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY (M.Tech) IN INDUSTRIAL AND TECHNOLOGY EDUCATION (BUILDING TECHNOLOGY)

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ABSTRACT

This study is designed to compare the effects of the characteristic properties of compressed laterite earth brick stabilized with palm leaf ash (PKA) and palm kernel fiber (KPF). Five research questions guided the study. Experimental research design was adopted for the study. The study was carried out in Building Technology Department, Federal Polytechnic Bida, Niger State. A total of 120 bricks of 222×110×70 were produced which 12 bricks each were stabilized with palm kernel fiber for 1%, 2%, and 3%. Also 12 bricks each were stabilized with palm leaf ash for each 5%, 10% and 15%. The materials used were Palm Kernel Fiber, Palm Leaf Ash laterite soil, and water. The tests carried out were sieve analysis, specific gravity test, compressive strength test, water absorption rate and abrasion resistance test. The findings showed that the specific gravity of the laterite ranging from 2.78 to 2.75 which is within the specification of Nigerian Building and Road Research Institute NBRRI of 2.7 to 3.0. The 28 days compressive strength of compressed laterite brick stabilized with PKF recorded average strength of 2.02 Nmm^2 at 1%, 2.07 Nmm^2 at 2%, and 2.26 Nmm^2 at 3%. They all conformed to NBRRI (2006) specification of 1.65Nmm^2, while the 28 day compressive strength of compressed laterite bricks stabilized with PLA recorded average strength of 1.72Nmm^2 at 5%, 1.79Nmm^2 at 10% and 1.81Nmm^2 at 15%. All result is in conformity with the NBRRI (2006) specification of 1.65 Nmm^2. The water penetration rate for the compressed laterite brick stabilized with PKF recorded average penetration rate of 10.18 at 1%, 11.52 at 2% and 12.19 at 3%. Only 3% produce higher penetration rate while compressed laterite stabilized with PLA recorded average water penetration rate of 11.58 at 5%, 10.63 at 10%, and 10.27 at 15%. All were in conformity with NBRRI specification of 12.5%. The abrasion resistance of the 28day compressed laterite brick stabilized with PKF recorded average abrasion of 1.40 at 1%, 1.27 at 2% and 1.68 at 3%. All result was conformity with the NBBRI specification of 6.9. While the abrasion resistance of the 28 day compressed laterite brick stabilized with PLA recorded average abrasion of 2.39 at 5%, 2.22 at 10% and 2.32 at 15% which is are in conformity with the NBBRI specification of 6.9. based on the findings of the study it was concluded that laterite used for the production of the bricks are of good quality and it was also concluded that the compressed laterite bricks stabilized with palm kernel fiber at 1% and 2% and 3% are in conformity with NBRRI specification of compressive strength, water absorption rate and abrasion resistance. While compressed laterite bricks stabilized with palm leaf ash should be improve to conform to NBRRI specification. Building professionals should sell this ideas of using the compressed laterite bricks stabilized with palm kernel fiber at 1% and 2% and 3% to their client and the low income earners should take advantage of it. The government should provide opportunity for the awareness campaign through workshops and social media and Building construction companies should focus on the importance of the use of these natural alternative building materials.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Cheap building materials may be necessary for the development of low cost housing in Nigerian. In particular, non-fired laterite bricks are attractive building material because they are inexpensive to manufacture compared to conventional block and burnt brick which are commonly used for building houses. Housing can be described as an essential component of human settlement that comparably ranks to the provision of food and clothing in the hierarchy of the basic primary elements required for human existence. At its most elementary level, it addresses the basic human needs providing shelter, offering protection against excessive cold, heat, rain, high winds and any other form of inclement weather, and also protection against unwanted aggression (Emmanuel, 2019). In quest to acquire this essential component of human settlement, there is a search for different building materials to be used.

Building materials have been playing an important role in the construction industry, Building materials are those materials put together in erecting or constructing structures, no field of engineering is conceivable without their use. Akanni *et al.* (2014). The materials include Cement, Sand, Water, Iron rod and some others. The cost of building materials poses a significant threat to both the construction industry and people aspiring to own houses (Anosike, 2009). While Idoro and Jolaiya (2010) affirmed that many projects were not completed on time due to the cost of materials, which have been on the increase.

It is obvious that cement is an essential building material. Cement is a grey powder made by burning clay and lime that sets hard when it is mixed with water. Cement one of the most important building materials, is a binding agent that sets and hardens to adhere to building units such as stones, bricks, tiles, etc. Cement generally refers to a very fine powdery substance chiefly made up of limestone (calcium), sand and clay (silicon), bauxite (aluminum) and iron ore, and may include shells, chalk, marl, shale, clay, blast furnace slag, slate combine together for the cement production. Cement, in general refers to adhesive substances of all kinds, but, in a narrower sense, the binding materials used in building and civil engineering construction. Cements of this kind are finely ground powders that, when mixed with water, set to a hard mass. Setting and hardening result from hydration, which is a chemical combination of the cement compounds with water that yields submicroscopic crystals or a gel-like material with a high surface area. Because of their hydrating properties, constructional cements, which will even set and harden under water, are often called hydraulic cements. (Dunuweera *et al.*, 2018).

The process of cement production has contributed to global warming. In view of this Emeka *et al.* (2016) reported that about 7% of carbon monoxide (CO_2) is released into the atmosphere during the cement production. This has negative effects on the ecology and future of human beings one of which is global warming. Research on alternatives to cement has so far centred on the partial replacement of cement with different materials. Reasons for finding alternatives to cement include the following: high cost of production, high energy demand and emission of CO_2 (responsible for global warming). In the third world countries, the most common and readily available materials that can partially replace cement without economic implication are bio-based materials and agro-based wastes; The alternative material that seems to be used for constructing building wall in Nigeria is compressed earth brick stabilized with agricultural wastes like rice husk, palm kernel fibre and palm tree ash, this is due to high cost of other building material. Oladipo and Oni (2012), which reported the trend in the cost of building materials, has envisaged great danger for the construction industry and the nation's economy in that there were instances of conflicts between building contractors and their clients over upward review in contract sums, and in an attempt to avert such conflicts and remain in the business, some contractors resorted to the use of substandard or insufficient materials for construction projects, which had contributed to cases of building collapse in the nation and it has leads to housing problem. The housing problem seems to be getting worse. It is estimated that Nigeria has a deficit of 17 million houses as of August 2012 and requires 700,000 houses annually compared to less than 100,000 currently being constructed, (National Housing Fund NHF, 2018).

According to the Federal Mortgage Bank of Nigeria (FMBN, 2019), Nigeria's housing gap is estimated to be in the region of 17 million units while home ownership is estimated as low as 25%. This is as the result of high cost of building materials "Housing deficit" refers to the number of shelters which do not have adequate conditions to be habitable, plus the number of housing units that need to be built to shelter all families who currently lack one and as a result share a shelter with another household in overcrowded conditions (Emanuel, 2019). It has been identified that 75% of the housing deficit in Nigeria is concentrated on families earning less than three times the minimum wage caught in the poverty cycle, families income are structurally limited and as a result they are unable to afford proper housing (World Bank, 2013). The construction industries and Government may be able to successfully deal with shortages in resources and increased prices for materials by looking at the potentials of natural agricultural wastes. Such laterite earth and Agricultural wastes such as Palm Leaf Ash and Palm Kernel Fibre mixed with laterite earth to mould compressed laterite brick.

Earth, undoubtedly is the oldest building material known. Even though building with earth once fell out of popularity when the modern building materials and methods were discovered, but then it gains its revival time following the energy crisis. Moreover, growing concern and interest about global environmental and ecological issue also increased the used of earth as a building material. Lateritic soil is widespread in tropical areas and subtropical climates. They are the most highly weathered soils in the classification system. The significant features of the lateritic soils are their unique color, poor fertility, and high clay content and lower cation exchange capacity. In addition, lateritic soils possess a great amount of iron and aluminum oxides, Iron oxides, existing mainly in the amorphous and crystalline inorganic forms, are one of major components in many soil orders (Tinivella, 2014).

Laterite is a weathered material composed principally of iron oxides, aluminum, titanium and manganese, and is classified as a soft porous earthy soil; often found 15 cm below the top soil (Chao *et al.*, 2022). Laterite defines as being formed by a process which causes the superficial decomposition of the parent rock, removal in solution of combined silica, lime, magnesia, soda and potash, and accumulation of hydrated iron, aluminium, titanium, and rarely, manganese. The latter were termed z-lateritic constituents. A residual rock with 90 percent or more of lateritic constituents is termed a true laterite. This true laterite is to be distinguished from the lesser groups, lithomargic laterites and lateritic lithomarges with 50 to 90 percent and 25 to 50 percent of lateritic constituents respectively and used for the moulding bricks.

Bricks are rectangular blocks of baked clay used for building walls, which are usually red or brown. A brick is a building material used to make walls, pavements and other elements in masonry construction. Riza *et al.* (2010) reported that, from experience, laterite bricks of 330 × 150 × 150 mm have proved to be economic and can be easily laid. It is an improvement on the fired clay bricks of 250 × 150 × 100 mm because 22 bricks are required per meter square of wall as against the 33 required for fired clay bricks. Consequently, the mortar required for jointing per square meter of wall is reduced significantly. Sometimes this brick is stabilized with natural agricultural waste products such as bamboo and other products of palm tree waste.

Palm tree is a kind of tree that grows in tropical regions and has a straight, tall trunk and many large leaves at the top of trunk. Palm kernel fibre is a waste gotten from the extraction of palm oil from the kernel disposed after the content is used. These wastes often cause great environmental degradation that usually results in pollutions, blocking of water channels and in most cases to outbreak of disease. Palm kernel fibre is a waste gotten from palm fruits after the oil is been extracted and it has the property of increasing hardness value of brick.

Walid *et al.* (2019) reported that the waste material, palm ash has been introduced as a competent binder in enhancing mortar and concrete properties. Palm ash is found to have great potential and it may be effectively utilized as construction material in reducing the CO_2 emission into the atmosphere and minimizing the cost of building materials such as concrete blocks and bricks that are used for construction without compromising the service life of the structures

Compressed Laterite Bricks (CLB) are masonry elements, which are small in size and have regular shape with verified characteristics obtained by the static or dynamic compression of earth in a humid state followed by immediate remolding. Compressed laterite bricks generally have a rectangular format and are full or perforated with vertical and/or horizontal indentations. (Oyelami *et al.,* 2016). The quality of raw materials involves proper selection of the sizes of the material. Therefore, the size of the laterite to be used for production of laterite compressed brick must be properly selected and this call for sieve analysis.

Sieve analysis is a grading by size of particles of powdered or granulated material done with a sieve. Sieve analysis is a commonly used and most often the only practice to determine size distribution of grained materials. Standard sieve analysis is the fastest and most widely used quality control procedure in any powder process control industry (Advantech, 2011). The proper selection of the size of laterite contribute greatly to the quality of compressed laterite brick

Compressed Stabilized Laterite Brick (CSLB) offered numbers of advantages. It increases the utilization of local material and reduces the transportation cost as the production is in situ, makes quality housing available to more people, and generates local economy rather than spending for import materials. Faster and easier construction method resulted in less skilled labour required, good strength, insulation and thermal properties, less carbon emission and embodied energy in the production phase, create extremely low level of waste and easily dispose. Off cause, no direct environmental pollution during the whole life cycle. Laterite brick also have the ability to absorb atmospheric moisture which resulted to create healthy environment inside a building for its occupant and the common source of moisture in temperate zones is rain water. Hence there is need for water penetration test on (CLEB).

Water penetration test is a method to assess the resistance to rain water penetration (Vilató, 2012**).** Water penetration into brick masonry walls leads to several problems such as efflorescence, mortar joint deterioration, interior moisture damages and spalling. When brick wall masonry structure experiences one or more issues related to water penetration, then it would be required to not only eliminate the source of water ingression but also deal with the deteriorated region of the wall (Madeh, 2017). Therefore, it's necessary to carry out water penetration rate test and specific gravity test in order to achieve quality brick.

The specific gravity is the ratio between the density of an object, and a reference substance. The specific gravity can tell us base on its value if the object will sink or float in our reference substance. Usually our reference substance is water which always has a density of 1 gram per millilitre or 1 gram per cubic centimetre.

Nigeria Building and Road Research Institute (NBRRI) proposed the following minimum specifications as requirements for laterite bricks: a bulk density of 1810 kg/m3, a water absorption of 12.5%, a compressive strength of 1.65 N/mm2 and a durability of 6.9% with a maximum cement content fixed at 5% (Raheem *et al*., 2012).

Adeyeye and Ololade (2013), again explained that compacting procedure also affect considerably the compressive strength of the compressed stabilized earth brick (CSEB). Compressive Strength is the maximum compressive stress that under gradually applied load a given solid material will sustain without fracture

Stabilizer for compressed earth brick (CSEB) playing an important role in creating bond between soil-stabilizers mixes. One of the main functions of the stabilizing medium is to reduce the swelling properties of the soil through forming a rigid framework with the soil mass, enhancing its strength and durability. The durability of a brick is determined by abrasion resistance test, abrasion resistance test is a test method that measure the relative abrasion resistance of standard conditions at room temperature. The abrasion resistance of a material provides an indication of its suitability for service in abrasive or erosive environment.

Nowadays, research and improved technology is motivating people to use lateritic bricks stabilized with agricultural waste as an alternative for sandcrete blocks in building houses because they do not require cement in molding the bricks during production, thereby reducing the building cost

There for, the researcher deems it necessary to compare the properties of compressed laterite earth brick stabilized with palm leaf ash and palm kernel fibre with Nigeria building and road research institute (NBRRI) standard requirement for low cost housing construction in order to ascertain their suitability.

1.2 Statement of the Research Problem

Building infrastructure is one of the basic need of man after food. The construction of buildings depends greatly on conventional materials such as cement, gravels, sand and others for the manufacturing of walling unit (brick and block). Cement undeniably is one of the most essential commodities in the construction sector because of its ability to bind the constituents into a single unit for building purpose. High demands of cement make it costly and inaccessible to the vast majority of people in developing countries like Nigeria where more than half of the population lives in poverty. This have certainly made decent accommodation beyond the reach of many people (Kareem *et al*., 2014).

More so, there are a lot of literatures on the use of natural and agricultural materials that can be used for the construction of low cost housing. Many scholars Nwofor (2012), and Abdulkadir (2016) in their study show the possibility of using agricultural and industrial waste for partial replacement of cement in building construction, which may possibly be an option of reducing high cost of building a house by low income earners, but there is use of cement which is an expensive conventional building material.

The continuing rising cost of conventional building material and its subsequent effects on construction in general has caused an increase in the housing deficit. This high cost of conventional building materials compel researchers into investigating different available local alternative building materials for walling unit. Nigeria is blessed with abundant natural resources such as Laterite, palm leaf ash and kernel residues which could be processed through stabilization to probably serve as affordable alternative walling unit with different effects in terms of their characteristic properties for its suitability and wide range of choice selection among them to low income earners for building construction. Therefore, the researcher compared the effect of the characteristics properties of compressed laterite earth brick stabilized with palm kernel fibres and palm leaf ash with NBRRI standard in order to explore their suitability for building.

1.3 Aim and Objectives of the Study

The study aimed to compare the effect of Palm Kernel Fibre, and Palm Leaf Ash on characteristic properties of compressed laterite earth brick. Specifically, the study:

1. Carried out sieve analysis of the laterite sample used for the production of compressed laterite brick stabilized with palm leaf ash and palm kernel fibre
2. Determined the specific gravity of laterite sample for the production of compressive laterite brick stabilized with palm leaf ash and palm kernel fibre
3. Compared the Compressive strength effect of compressed laterite Brick stabilized with palm kernel fibre and Palm Leaf Ash.
4. Compared the water penetration rate effect of Compressed laterite Brick stabilized with palm kernel fibre and Palm Leaf Ash.
5. Compared the resistance to abrasion effect of Compressed laterite Brick stabilized with palm kernel fibre and Palm Leaf Ash.

1.4 Significance of the Study

The findings of this study will benefit the low income earners through workshops and conferences of the different characteristics properties effects among compressed laterite brick stabilized with palm fibers and those stabilized palm leaf ash. Hence, this will give them wider choice opportunity in selecting the one they prefer for their building constructions based on the recommendation of the study.

Building professionals will also benefit from the findings since it will reveal comparative effect result of palm kernel fibres and palm leaf ash through journals and publications of the compressed laterite brick in terms of both compressive strength and water penetration rate characteristic properties hence avail them with knowledge on how to monitor, recommend and supervise the production of compressed laterite brick stabilized with palm kernel fibre and palm leaf ash in the construction of building.

Construction companies will gain source information through workshops and conferences on the comparative effect of compressed laterite brick stabilized with palm kernel fibre and those stabilized with palm leaf ash and sell the idea to the clients for cheaper production of low cost housing, thereby increasing their productivity as well as profits. Government will benefit from this study through publication since the study will serve as a document that contained useful information on the comparative effect kernel (PKF) and (PLA) of the compressed laterite brick on their characteristic properties that could be used for production of low cost housing and use media to provide enlightenment and awareness to Nigerians especially low income earners which also minimizes high housing deficit.

The society as a whole will benefit from the findings of this study since it will provide information through awareness campaign during radio programs and community meetings on the comparative effect of these agricultural wastes, that is, PLA and PKF to be used as compressed laterite brick (CLB) stabilizers for production of low cost housing there by, saving the society from the effect of environmental pollution caused by dumping of these agricultural wastes.

1.5 Research Questions

The following research questions guided the study:

1. What is the sieve analysis of the laterite sample for the production of compressed laterite brick stabilized with palm leaf ash and palm kernel fiber?
2. What is the specific gravity of the laterite sample for production of compressive laterite brick stabilized with palm leaf ash and palm kernel fiber?
3. What is the compressive strength of compressed laterite brick stabilized with palm kernel fibres and Palm Leaf Ash?
4. What is the water penetration rate effect of compressed laterite brick stabilized with Palm Kernel Fibres and Palm Leaf Ash?
5. What is the abrasion resistance effect of compressed laterite Brick stabilized with palm kernel fibre and Palm Leaf Ash?

1.6 Scope of the Study

The study compared the effect of compressed laterite brick stabilized with palm Kernel fibre and palm leaf ash. Specifically, the study carried out the sieve analysis of the sample used for the production of compressed laterite brick stabilized with palm leaf ash and palm kernel fiber, Determined the specific gravity of the laterite sample used for production of compressed laterite brick, Determined the differences in compressive strength, water penetration rate, and abrasion resistance of compressed laterite Brick stabilized with palm kernel fibres and Palm Leaf Ash of 225mm × 150mm × 115mm. The quantity of chemical content of the Palm kernel fibre and palm leaf Ash was not carried out since they know to be pozzolanic and cellulose.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Conceptual Framework

The various stages are considered in the production of compressed laterite earth bricks. Various step considered in the realization of the purpose of the study is shown in Figure 2.1.

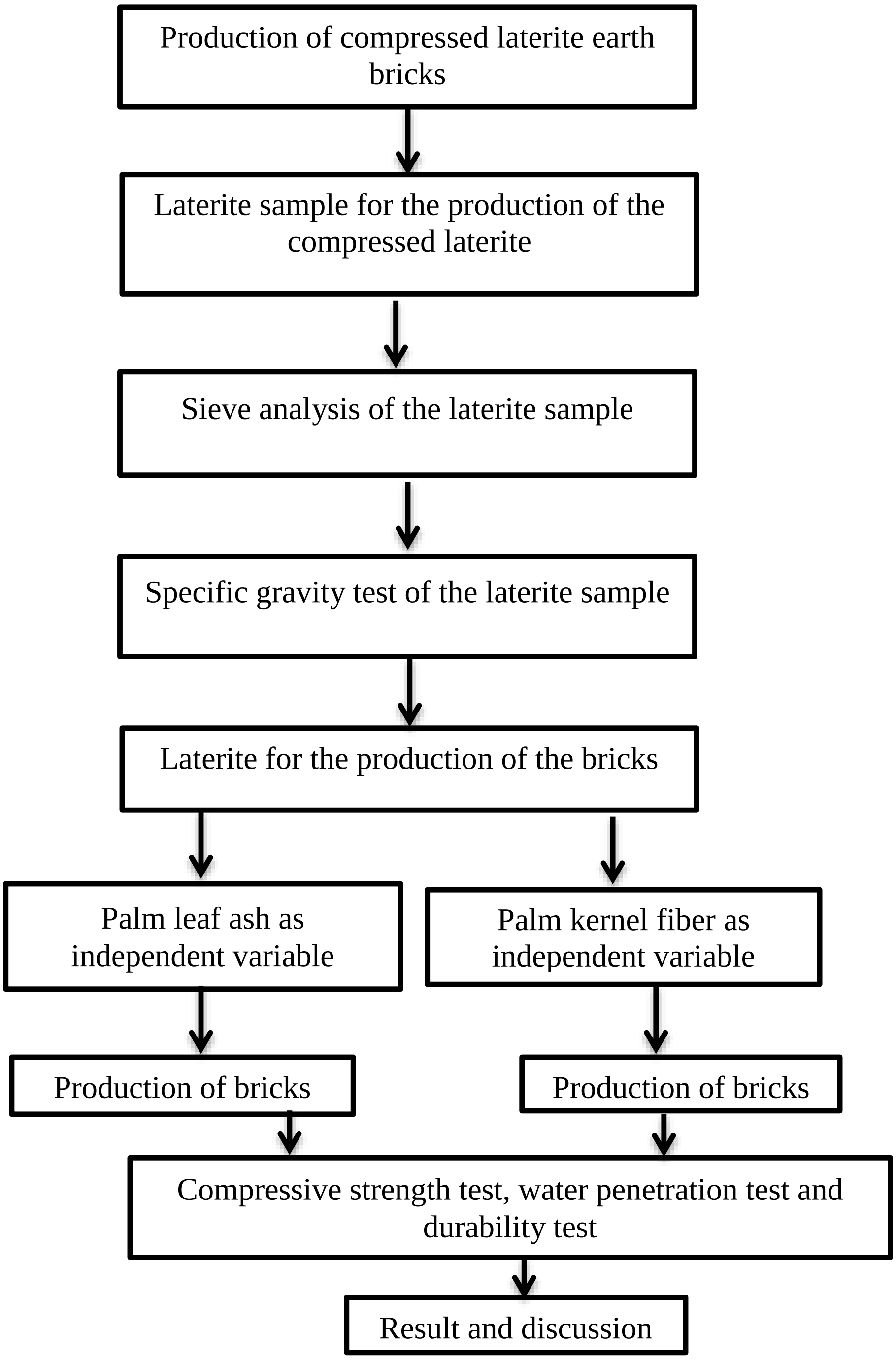

Figure 2.1: Conceptual Framework

For quality production, the laterite material was sourced and also tested to ensure it suitability. Specific gravity test and sieve analysis test were the test that was carried out. The specific gravity is the ratio of the density of a substance to the density of a reference substance; equivalently, it is the ratio of the mass of a substance to the mass of a reference substance for the same given volume. Specific gravity test is done to measure the strength or quality of the material (Nissa, 2015). Specific gravity of the soil is one of the engineering properties that shows whether the soil is suitable for the production of compressed laterite earth brick. While the determination and knowledge of the particle size distribution is an essential part of the quality control process for industrial products. From incoming and production control to research and development sieve analyses are used to determine a number of parameters or simply the particle size. (Luka & Hanke, 2016). Sieve analysis was carried out to determine the load bearing capacity of the laterite.

The stabilizers which are the independent variables that is, palm leaf ash and palm kernel fibers are agricultural waste which are capable of causing environmental pollution if they are not used but they also possess qualities for improvement of compressed laterite earth brick. The bricks were produced after the laterite material was prepared and measured, the stabilizers were also measured then mixed together befor water was added then the mixture was poured into the compressed moulding machine and compressed properly after which the it was removed and cover with nylon for curing. The compressive strength test was carried out at 7^{th} day, 14^{th} day, 21^{st} day and 28^{th} day but the water penetration and durability test were carried out on the 28^{th} day, the results were obtained using the proper formula.

2.1.1 Cost of building materials

According to the case study evidence, horizontal inequalities appear to be most likely to lead to conflict where they are significant, consistent across dimensions, and widening over time. Apparently, due to security challenges on different geographical zone in the country; this increases the companies‟ overhead and insurance costs which affect the total construction cost. (Nnadi *et al*. 2022). While Idoro and Jolaiya (2010) affirmed that many projects were not completed on time due to the cost of materials, which have been on the increase. Besides timely completion, high prices of building materials form a crucial constraint to improving housing conditions in the low-income earning countries, Nigeria inclusive.

The construction industry is a vibrant sector of any economy since infrastructural development forms one of the indicators used in measuring a country development. Such infrastructural development depends greatly on conventional materials such as cement, gravels and sand for the manufacturing of concrete and bricks. Cement undeniably is one of the most essential commodities in the construction sector. As a result of high cost and inaccessibility of cement the vast majority of people in developing countries where income levels are low and about half of the population ling in poverty, it certainly not surprising that many people cannot afford decent housing accommodation. The rising cost of building materials and it subsequent effects on construction in general have caused an increase in the housing deficit.

Oladipo and Oni (2012), Reporting the trend in the cost of building materials, has envisaged great danger for the construction industry and the nation's economy in that there were instances of conflicts between building contractors and their clients over upward review in contract sums, and in an attempt to avert such conflicts and remain in the business, some contractors resorted to the use of substandard or insufficient materials for construction projects, which had contributed to cases of building collapse in the nation.

Materials had been playing an important role in the construction of Building industry. They were all naturally occurring in the ancient times, for example, stone, wood, straws, clay, lime, and brick (Taylor, 2013). As the building techniques were improving, simple composite materials, combined by means of mixing and/or heat treatment, were developed. A typical example is concrete, which was developed by the Roman Empire. Due to advances in science and technology at the beginning of the 20th century, materials with better performance and durability were introduced, for example, reinforced concrete, steel, plastics, and metal (Taylor, 2013). Idoro and Jolaiya (2010) find that building materials alone account for 50% to 60% of project cost and control about 80% of its schedule.

One of the major constraints in the Nigerian construction industry today has been the rapid inflation in the cost of the building materials. It is obvious that the situations arising from the rapid increase in the cost of building materials have degenerate to shortages of housing with the millions of middle- and low-income families being priced out of the market for home ownership all across Nigeria. However, findings of other researchers, Mojekwu, Idowu, and Sode (2013); Idoro and Jolaiya (2010), concluded that factors such as the change in government policies and legislation, scarcity of building raw materials, fluctuation in the cost of fuel and power supply, inadequate infrastructural facilities, corruption, fluctuation in the cost of plant and labor, seasonal changes, fluctuation in the cost of transportation and distribution, political interference, local taxes and charges, fluctuation in the interest rates and the cost of finance, the inflation, and fluctuation in the exchange rate of Naira were many of the recipes for the rising cost of building materials in Nigeria.

2.1.2 Laterite for the production of stabilize compressed laterite brick

The term laterite in a broad sense, is define as a highly weathered natural material with high concentration of hydrated oxides of iron or aluminium (so-called oxides), as a consequence of residual accumulation and/or absolute enrichment, by components transported in solution or as detrital material (Georges & Vera, 2018). Laterite is a weathered material composed principally of iron oxides, aluminum, titanium and manganese, and is classified as a soft porous earthy soil; often found 15 cm below the top soil (Chao *et al*., 2017).

Laterite is a consolidated product of humid tropical weathering predominantly composed of goethite, hematite, kaolin, quartz, bauxite and other clay minerals. It is red, brown to chocolate colored at the top showing hollow, vesicular, and botryoidally structure. It changes progressively from a nodular iron oxide-rich zone at the top to structure less clay-rich zone and ultimately merges with the partially altered to unaltered bedrocks. Laterite carry enriched grade of Fe, Al, Mn, Ni, Cu, Ti, and V. Lateritic cover can turn into low-grade iron, aluminum, nickel-copper and gold deposits with the increase of metal content (Lemougna *et al.* 2011). Laterites vary greatly in structure, but can be reduced to the following three structural patterns:

(a) The indurated elements form a continuous, coherent skeleton;

(b) The indurated elements are free concretions or nodules in an earthy matrix;

(c) The indurated elements cement pre-existing materials.

These structural patterns exhibit great variability in relation to the shape and size of the elements involved and the degree of induration. The degree of hardness ranges from products that are practically unconsolidated and scarcely coherent to the hardest blocks which can be broken only with a hammer. Induration is an empirical criterion, as it is impossible to give quantitative expressions to any character related to the mechanical properties of the material. Induration is a state in which the hard brittle consistency of the medium is not affected by humidity. Induration, which involves the precipitation of goethite in a reticular network, is influenced by composition and the extent of crystallization of the components in the soil: the higher the oxide content, the greater the induration. In other words, hardness increases as the iron content increases; the hardest laterites are also the least hydrated.

Laterites vary in color, but are usually brightly colored. The shades most frequently encountered are pink, ochre, red and brown; however, some occurrences are mottled and streaked with violet, and others exhibit green marbling. A single sample may exhibit a whole range of colors merging more or less perceptibly into one another in a variety of patterns and forms. Laterites owe their color to iron oxides in various states of hydration and sometimes also to manganese. Their mineralogy generally involves quartz, kaolinite, hematite, goethite and sometime maghemite. Kaolinite is always present with iron oxides.

The physical properties of lateritic soil vary according to the mineralogical composition and particle size distribution of the soil. The granulometry can vary from very fine to gravel according to its origin, thus influencing geotechnical properties such as plasticity and compressive strength. One of the main advantages of lateritic material is that it does not readily swell with water. This makes it an excellent packing material particularly when it is not too sandy (Lemougna *et al.*, 2011).

Stabilization processes are very complex because many parameters come into play. The knowledge of soil properties can help to better consider what changes, the economic studies (cost and time), as well as production and construction techniques to use. The simplest process consists of taking soil and drying it in open-air. It is the, rammed earth, adobe, and brick dried in the sun, widely used in the majority of African countries. More elaborate processes can include heat treatment, or mixing soil with ordinary Portland cement, lime, and others (Lemougna *et al*., 2011).

2.1.3 Brick as a building material

A brick is a building material used to make walls, pavements and other elements in masonry construction. According to Riza *et'al*. Isaac Olufemi Agbede and Manasseh Joel report that, from experience, laterite bricks of 330 × 150 × 150 mm have proved to be economic and can be easily laid. It is an improvement on the fired clay bricks of 250 × 150 × 100 mm because 22 bricks are required per meter square of wall as against the 33 required for fired clay bricks. Consequently, the mortar required for jointing per square meter of wall is reduced significantly.

Brick can be classified in several ways. ASTM standard categorized brick as

1. building brick (ASTM C 62)
2. facing brick (ASTM C 216),
3. hollow brick (ASTM C 652), and
4. Thin veneer brick (ASTM C1088).

The building brick can be used in load bearing and non-load bearing walls and also for insulation purpose. Brick can also be categorized as clay bricks, mortar brick, fired or unfired brick and others. CSEB brick is distinguished with conventional fired bricks through its production process. CSEB brick requires compaction whether it's static, dynamic or vibro-static methods and also the content of stabilizer added for gaining its strength. A striking contrast between CSEB and conventional bricks is the energy consumed during the production process and carbon emission. CSEB brick creates 22 kg CO2/tone compare to that of concrete blocks (143 kg CO2/tonne), common fired clay bricks (200 kg CO2/tonne) and aerated concrete blocks (280 – 375 kg CO2/tonne) during production In average, cement stabilized earth bricks consumed less than 10% of the input energy as used to manufacture similar fired clay and concrete mansory unit (Riza *et al*., 2010).

2.1.4 Compressed earth bricks

Compressed earth bricks (CEBs is the "masonry elements, which are small in size with regular and verified characteristics obtained by the static or dynamic compression of earth in a humid state followed by immediate demolding".

Compressed laterite bricks are principally made of raw earth and owe their cohesion in a humid state and in a dry state essentially to the clay fraction within the laterite; an additive can, however, be added to the earth to improve or enhance characteristics of the product. The final characteristics of CLBs depend on the quality of the raw materials used (laterite, additive) and on the quality of the execution of the various manufacturing stages (preparation, mixing, compression, curing). Compressed laterite bricks standards (Oyelami & Rooy 2016).

Production of CSEB required only 3 stages which are:

1. soil preparation and mix
2. Compression
3. And the curing.

In soil preparation, it needs careful and correct selection of the soil to get the best result and after the mix was put in the mold, it should be given proper compressive load. Curing method in CSEB production usually take advantage from natural humid where bricks could stacked immediately after compression to prevent rapid drying out hence the brick is moist cured under polythene sheet in the open air for about 28 days if cement is used as a stabilizer (Riza *et al*., 2010).

2.1.5 Palm kernel fibre as stabilizers for compressive earth brick

Palm kernel fibre is a waste gotten from the extraction of palm oil from the kernel disposed after the content is used. These wastes possess a great environmental degradation that usually results in pollutions, blocking of water channels and in most cases to outbreak of disease. Osita *et al.* (2017) concludes that, the hardness value of the PKF composites increases which is attributed to the increase in the ratio of PKF of each sample. Paladugula *et al.* (2015) report that Chemical analysis of palm fibre shows high cellulose content. The hemicellulose content is quite low when compared with other natural fibres. Cellulose content is responsible for long fibre chain that ranged from 28 to 53 % for palm fibres. Hemi-cellulose leads to disintegration of cellulose microfibrils that decrease the fibre strength between 12 to 43 % for palm. Paladugula *et al.* (2015) concluded that, the characterization of palm fibres provides new hope for natural fibre research to compete with hazardous synthetic fibre with its excellent properties.

The density of palm fibres is significantly lower than that of the popular glass fibre, carbon fibre, and others, but produces 20% better specific strength. The tensile strength and Young's modulus was significantly higher than any other natural fibres ever investigated. The high cellulose content and lower lignin content ensure better mechanical strength. Thus this characterization results firmly confirms the possibility of using this fibre for the manufacture of sustainable fibre reinforced polymer composite agricultural waste, hence, was used as stabilizer for Production of compressed stabilized earth brick (CSEB) together with the laterite.

2.1.6 Palm leaf ash as stabilizers for compressive earth brick

Walid *et al.* (2019) reported that The waste material palm leaf ash has been introduced as a competent binder in enhancing mortar and concrete properties. palm leaf ash is found to have great potential and it may be effectively utilized as construction material in reducing the CO_2 emission into the atmosphere and minimizing the cost of construction without compromising the service life of the structures. According to Emeka *et al.* (2016) Based on the chemical test, the oil palm frond ash can be classified as a pozzolanic material because the percentage sum of its SiO_2, Al_2O_3 and Fe_2O_3 components (52.97%) exceeds the minimum requirement of 50%. Pozzolanic materials are natural or artificial materials which contains silica and alumina or ferruginous materials in a reactive form, the natural pozzolana are volcanic ashes, tuffs and other diatomaceous earth, artificial pozzolana are agricultural and mines wastes. Pozzolanic materials are not cementitious in themselves but when finely grounded, contains some properties which at ordinary temperature will combine with lime and shale in the presence of water to form compound which have low solubility character and possess cementitious properties.

Palm frond ash which is an agricultural waste poses certain amount of pozzolanic materials. Emeka *et al.* (2016) argued that, based on the chemical test, the oil palm frond ash can be classified as a pozzolanic material because the percentage sum of its SiO_2, Al_2O_3 and Fe_2O_3 components (52.97%) exceeds the minimum requirement of 50%. Pozzolanic materials are natural or artificial materials which contains silica and alumina or ferruginous materials in a reactive form, the natural pozzolana are volcanic ashes, tuffs and other diatomaceous earth, artificial pozzolana are agricultural and mines wastes. Pozzolanic materials are not cementitious in them but when finely grounded, contains some properties which at ordinary temperature will combine with lime and shale in the presence of water to form compound which have low solubility character and possess cementitious properties which can be use to make compressed laterite bricks (CLB).

2.1.7 Sieve analysis

Sieve is an instrument used to carryout sieve analysis. Sieve analysis is a grading by size of particles of powdered or granulated material done with a sieve. Sieve analysis is a commonly used and most often the only practice to determine size distribution of grained materials. Standard sieve analysis is the fastest and most widely used quality control procedure in any powder process control industry (Advantech, 2001). The Plate I, shows the image of sieves of different sizes.

Plate I: Sieves

The determination and knowledge of the particle size distribution is an essential part of the quality control process for industrial products. From incoming and production control to research and development sieve analyses are used to determine a number of parameters or simply the particle size (Luka & Hanke, 2016).

2.1.7.1 Sieving methods

1. Vibrational sieving: Vibrational sieving submits the sample to three dimensional movements. A vertical throwing motion is superimposed by a circular movement. This mechanism causes the particles to be evenly distributed over the entire sieving surface and to be thrown into the air where they ideally change their orientation in a way that allows them to be compared to the sieve apertures in all possible dimensions.
2. Wet sieving: A special case of vibratory sieving is wet sieving. Agglomerates, electrostatic charging or a high degree of fineness can all make the sieving process difficult and in such cases wet sieving may be called for. This involves washing the sample through the sieve stack in a suitable medium which is usually water.
3. Horizontal sieving: Here the sample is subjected to a circular horizontal movement. This two-dimensional motion does not cause the particles to change their original orientation. This method is particularly suitable for longish, disk-shaped or fibrous samples (sieving with circular motion.
4. Tap sieving: The use of tap sieve shakers is stipulated in a number of standards. In the tap sieving process, a circular horizontal movement is superimposed by a vertical tapping motion. This particular method will be adopted in this study in other to achieve the desired result
5. Air jet sieving: To obtain a sieve cut by air jet sieving only one sieve is used instead of a stack of sieves, and the sieve itself is not put into motion. An industrial vacuum cleaner generates low pressure inside the sieve chamber. The sucked-in air escapes with high speed from the rotating slit nozzle below the sieve and disperses the particles which can then be compared to the sieve apertures. When the particles hit

the sieve lid they are not only redirected but also deagglomerated. The particles which are small enough are then transported through the sieve mesh and sucked in.

Step for Sieve Analysis.

A complete sieving process consists of the following steps which should be carried out precisely and carefully.

1. Sampling.
2. Sample division (if required).
3. Selection of suitable test sieves.
4. Selection of sieving parameters.
5. Actual sieve analysis.
6. Recovery of sample material.
7. Data evaluation.
8. Cleaning and drying the test sieves.

2.1.8 The specific gravity of the laterite soil

The specific gravity is the ratio of the density of a substance to the density of a reference substance; equivalently, it is the ratio of the mass of a substance to the mass of a reference substance for the same given volume. Specific gravity test is done to measure the strength or quality of the material (Nissa, 2015). Specific gravity of the soil is one of the engineering properties, which plays an important role in analysis of geotechnical problems. The specific gravity of soil is one of the basic properties that commonly known by a symbol with Gs. This value is a measurement of soil particle density and related to the equivalent volume of water. The degree of saturation and void ratio depend on it. (Azlan *et al.*, 2015).

Specific gravity is the ratio of the mass of a given volume of material to the mass of an equal volume of water at a temperature of 4°C. The specific-gravity values for soil particles are a useful parameter needed for all calculations involving void ratio, porosity or the degree of saturation. For soils these include compaction, consolidation, permeability, shrinkage limit tests and particle-size distribution by sedimentation analysis. In laterite soils the particles generally have a specific gravity between 2.55 and 4.6.

According to Aguwa's (2013). Traditional point of view, lateritic soils, which are reddish brown in color, have been used as blocks for buildings without any cement content. Recently, modern builders started introducing some percentage of cement to laterite for molding stronger blocks, because of high cost of sandcrete blocks. A major advantage of the use of laterite instead of sand in molding building blocks is the low cost, due to small quantity of cement required to produce blocks with adequate compressive strengths as well as low cost of transporting laterite. The compressive strength of laterite-cement blocks increased steadily with increase in percentage of cement content up to 20% but decreased at cement contents above 20%. From the study, NBRRI proposed the following specifications as requirements for laterite bricks: bulk density of 1810kg/m3, water absorption of 12.5%, compressive strength of 1.65N/mm2 and durability of 6.9% with maximum cement content fixed at 5% (Raheem *et al*., 2012).

2.1.9 Compressive strength of compressed earth brick

Compressive strength test machine is use for measuring the maximum amount of compressive load a material can bear before fracturing. The test piece, usually in the form of a cube, prism, or cylinder, is compressed between the platens of a compression-testing machine by a gradually applied load (see Plate II). Compressive Strength is the maximum compressive stress that under gradually applied load a given solid material will sustain without fracture. The compressive strength of a brickwork is simply assumed as the ratio between the collapse load and horizontal cross section section. Sterpi *et al.* (2006). CSLB must meet the standard of NIS; this is because it helps in transmitting the load of overlaying structural element to the foundation. Thus Load bearing wall is a structural element. It carries the weight of a house from the roof and upper floors, all the way to the foundation. It supports structural members like beams (sturdy pieces of wood or metal), slab and walls on above floors above. A wall which doesn’t help the structure to stand up and holds up only itself is known as a non-load bearing wall. It doesn’t support floor roof loads above. It is a framed structure. Most of the time, they are interior walls whose purpose is to divide the structure into rooms.

Plate II: Compressive Strength Test Machine

The compressive strength of a brickwork is simply assumed as the ratio between the collapse load and horizontal cross section. According to Sterpi *et al*. (2006) CSLB must meet the standard of NIS; this is because it helps in transmitting the load of overlaying structural element to the foundation. Thus Load bearing wall is a structural element. It carries the weight of a house from the roof and upper floors, all the way to the foundation. It supports structural members like beams (sturdy pieces of wood or metal), slab and walls on floors above. A wall which doesn’t help the structure to stand up and holds up only itself is known as a non-load bearing wall. It doesn’t support floor roof loads above. It is a framed structure. Most of the time, they are interior walls whose purpose is to divide the structure into rooms.

Bahar *et al.* (2012) observed that by using dynamic compaction energy dry compressive strength increases by more than 50% but for vibro-static compaction increases slightly for about 5%. On this note, compressive strength of palm kernel fibre stabilized compressive earth brick can be improved by using a lever machine for molding.

Compressive strength/ crushing strength of brick test is calculated by using the equation, F= P/A. Where, F= Compressive strength of the brick (in N/mm^2), P= Maximum load applied to the brick (in N) and A= Cross sectional area of the specimen (in mm^2).

2.1.10 Water penetration rate of compressed laterite earth brick

Water penetration test a method to assess the resistance to rain water penetration (Vilató, 2012**).** Water penetration into brick masonry walls leads to several problems such as efflorescence, mortar joint deterioration, interior moisture damages and spalling. When brick wall masonry structure experiences one or more issues related to water penetration, then it would be required to not only eliminate the source of water ingression but also deal with the deteriorated region of the wall (Madeh, 2017)

Water content is the quantity of water contained in a material such as soil, rock, ceramics, fruit or wood. It is the amount of water present in a moist sample can be expressed on wet or dry basis.

Water absorption rate is determined by measuring the decrease in mass of saturated block and surface dry sample (Makinde, 2007).

Water absorption is a function of clay and cement content and usually related with the strength and durability of earth bricks and therefore it is important to determine the rate of water absorption and specific gravity of earth bricks. Water absorption test on bricks are conducted to determine durability property of bricks such as degree of burning, quality and behaviour of bricks in weathering (https://theconstructor.org). To determine the water penetration rate a pipe is connected to a source of water and to an iron plate that has holes to enable the water to pass through and spray on the bricks. See plate III.

Plate III: Water Sprayer

2.1.11 The durability of compressed laterite earth brick

The durability of a brick is determined by abrasion resistance test, abrasion resistance test is a test method that measure the relative abrasion resistance of standard conditions at room temperature. The abrasion resistance of a material provides an indication of its suitability for service in abrasive or erosive environment.

Abrasion testing is a necessity for manufacturers who are interested in producing high-quality products with a long lifespan. With a multitude to different testing methods available, each with their own nuances, it can be difficult to decide which test to use (Alan, 2017).

2.1.11.1 Important of wear testing

The primary reason companies conduct abrasion resistance tests is to ensure they are producing a quality product that is free from defects; consistent in performance; and will endure throughout its life cycle. The ideal solution would be to analyze a material's wear resistance in actual use. Unfortunately, this approach often takes many years before useful data becomes available. Additionally, the cost of conducting a field test could be prohibitive and the complexity of identifying and monitoring the influences can be unwieldy. An accelerated laboratory test is appealing because companies can compress the life span of a product into a much shorter duration within a controlled and monitored environment. Plus, it allows materials to be tested in the same manner, and under the same conditions.

For many products, an established test protocol has been developed to ensure test results are comparable. This allows a company to demonstrate they meet a minimum performance standard. Or testing can help a company gain a competitive advantage by showing how it performs compared to the competition. Another advantage of testing is to evaluate the impact of supplier or material changes before they are implemented. In today's competitive environment, lower cost options may be appealing but have unintended negative consequences on product quality.

While a lab test may not represent the actual conditions materials are exposed to, testing can duplicate many real world conditions allowing you to have higher reproducibility with your evaluations. And following an established methodology helps ensure your results will be both repeatable and reproducible.

2.1.11.2 Different types of wear testing instruments available to manufacturers

There are numerous instruments available that can simulate different types of wear modes. Taber's solutions are versatile, affordable, easy to operate and allow the user to evaluate:

1. Two-body abrasive wear – hard particles are forced against and moved along a solid surface;
2. Sliding wear – occurs between two solid bodies and is generated from a reciprocating motion;
3. Mar abrasion – permanent deformations that have not ruptured the surface of a coating, but tend to disfigure or change the appearance of its surface;
4. Rolling abrasion (or three-body wear) – happens when abrasive particles or debris are allowed to "roll" between the surface and a contacting substance.

2.2 Review of Related Empirical Studies

Owus *et al.* (2018) studied the effects of palm kernel shell on the compressive strength and saturated surface dry density of stabilized soilcrete (SC) at the federal university of technology owerri. Preliminary tests were carried out for identification and classification of laterite and palm kernel shell (PKS). Compressive strength (CS) test on different percentage of PKS, and effect of cement aggregate ratio (CAR) on the saturated surface dry density (SSDD) of the stabilized palm kernel shell soilcrete were also carried out. A uniformly graded clayey SAND (SCl) laterite with low plasticity and uniformly graded palm kernel shell (PKS) with maximum grain size of 13.2 mm was used. The stabilized PKS soilcrete blocks were produced using CAR of 1:9, 1:12.33 and 1:19 at 10%, 20%, 30%, 40% and 50% replacement of laterite with PKS, with varying w/c ratios of 0.75, 0.77, and 0.80. Compaction pressure of 4.14 MPa was gradually applied to produce 150

× 150 × 150 mm SC cubes. A total of 162 cubes were produced from 54 mix ratios and 3 cubes for each mix ratio; the average compressive strength (CS) and saturated surface dry density (SSDD) were determine after 28 th day curing using. The results from the compressive strength at different replacement levels shows that, the optimal CS value occurred at 20% replacement of laterite with PKS with the numerical value of 1.68 MPa at 1:9 CAR and 0.80 w/c for compaction effort of 4.14 MPa. The SSDD value for CAR of 1:9, 1:12.33 and 1:19, at 0.75 w/c, 0.77 w/c and 0.80 w/c decreased as the %PKS content increases. Similarly, the SSDD decreases as the CAR increases and the maximum SSDD values was obtained at 1:9 CAR for 0.75, 0.77 and 0.80 w/c.

The following conclusions drawn shows that the CS of soilcrete block (SCB) increased as %PKS increased from 0 to 20% and reduced with further increase in PKS content while the SSDD decreased as %PKS increased from 0 to 50%. Likewise, it was observed that increase in CAR reduced the saturated surface dry density (SSDD) at the same w/c and compaction effort. The optimal percentage replacement of laterite with PKS in SCB was 20%, which implies that the PKS possesses the potential for use in the production of compressed stabilized SC and hence recommended for use. The study review is related to the present study because agricultural waste is used to stabilized the brick, compressive test was carried out to determine the quality of the brick while the present study will also determine and compare the compressive test of palm leaf ash and palm kernel fibre. The study differs in production process as the present study abdoted manual method. The study also differ as the present study is on full replacement and not partial replacement.

Ismail and Yaacob (2011) worked on the development of a new, low-cost building material that is composed of non-fired, pressed laterite bricks incorporating oil palm empty fruit bunches (OPEFB). The main aim of the research was to study the physical and mechanical properties of laterite brick reinforced with OPEFB fibre, including dimensions, weight, density, water absorption and compressive strength. The tests were carried out according to BS 3921:1985 for water absorption and compressive strength tests. The mix proportion of the control bricks was 70% soil, 24% sand, and 6% cement. Meanwhile, the OPEFB fibre contents ranged from 1% to 5% by weight of cement. The specimens were taken from a total of 120 bricks. The findings withdrawn from this research were: firstly, the density of laterite bricks was decreased with the increase in the OPEFB fibre content of the bricks. Secondly, it was found that the addition of the OPEFB fibres improved the compressive strength of the bricks, and the maximum compressive strength determined in this study for bricks was with 3% fibre content. Finally, the water absorption results indicated a small increase in water absorption with the increase in the OPEFB fibre content in laterite bricks. The study reviewed is related to the present study in their design, both studies adopted experimental Research Design just as the present study also adopt experimental Research Design, compressive test and water absorbance test was carried out to determine the quality of the brick while the present study also determined and the compressive test of palm leaf ash and palm kernel fibre. The study differs in the objective, as the present study also compare the compressive strength and moisture content of the brick.

Otunyo and Chukuigwe (2018) investigated the impact of palm bunch ash (PBA) on the stabilization of poor lateritic soil at River state university Nkpolu. The palm bunch ash in percentages by weight (0%, 20%, 25% and 30%) was added to the lateritic soil. The 0% PBA acted as the control. The following parameters of the (lateritic soil+ palm bunch ash) were tested in the laboratory: Maximum Dry Density (MDD), Optimum Moisture Content (OMC), California Bearing Ratio (CBR) and unconfined compression strength (UCS). The values of the MDD, OMC, CBR and UCS increased as the PBA content in the lateritic soil was increased up to between 25% PBA, thereafter the values started to decrease. The UCS of the (lateritic soil + palm bunch ash) specimen cured for 14 days were also found to higher than that of 28 days curing period at 20% PBA content. The UCS values for 14 days became higher than that at 28 days at 25% PBA content. The PBA can be used as a lateritic soil stabilizer between (20-25%) PBA content. The study review is related to the present study because compressive test and water absorbance content was carried out to determine the quality of the laterite soil while the present study also determined and compare the compressive test of palm leaf ash and palm kernel fibre. The study differs in geographical location.

Amu *et al.* (2008) conducted a study on The Effects of Palm Kernel shells in Lateritic Soil for Asphalt Stabilization for possibility of complementing poor lateritic soils with Palm Kernel Shells (PKS) and subsequent stabilization of the resulting composite mix with asphalt by determining specific gravity compressive strength and moisture content. This study was conducted in the Transportation laboratory of civil Engineering Department, Obafemi Awolowo University. Ile-Ife, Nigeria. , each of the composite mixes and the natural lateritic soil were subjected to percentages by weight of asphalt stabilization (2, 4, 6, 8 and 10%), while PKS percentages of 25, 50, 75 and 100% by weight were used for the tests. Preliminary and strength tests were performed on the natural and composite mixes to determine their engineering properties under laboratory conditions. The results showed that the addition of 25% PKS to the natural soil caused PI to increase to 19.1% and then subsequently reduced to 17.7 at 4% asphalt stabilization. The addition of 4% asphalt to 75% laterite and 25% PKS increased Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) to 1560 kg m-3 and 23.0% respectively, with a reduction in average CBR to 1.15% (unsoaked) and 0.55% (soaked). With the same composite mix, the uncured compressive strength was 36.87 kN m-2 while cured was 927.54 kN m-2 and a shear resistance of 28.48 kN m-2 was observed. The major finding revealed that the resulted stabilized soils mixes obtained were inadequate for subgrade, sub base and base courses in road construction.

The study reviewed is related to the present study because it determined the specific gravity and moisture content of laterite soil while the present study is also design to determine the specific gravity and moisture content of compressed laterite brick. The study also uses agricultural waste for stabilization of laterite soil. The study differs as its seek to improve lateritic soil and the present study seek to improve compressed laterite brick.

Otunyo and Chukuigwe (2018) conducted a study on Investigation of the impact of palm bunch ash on the stabilization of poor lateritic soil in department. of civil engineering, rivers state university, Nkpolu, Portharcourt, rivers state Nigeria. This study investigated the impact of palm bunch ash (PBA) on the stabilization of poor lateritic soil. The palm bunch ash in percentages by weight (0%, 20%, 25% and 30%) was added to the lateritic soil. The 0% PBA acted as the control. The following parameters of the (lateritic soil+ palm bunch ash) were tested in the laboratory: Maximum Dry Density (MDD), Optimum Moisture Content (OMC), California Bearing Ratio (CBR) and unconfined compression strength (UCS). The values of the MDD, OMC, CBR and UCS increased as the PBA content in the lateritic soil was increased up to between 25% PBA, thereafter the values started to decrease. The UCS of the (lateritic soil + palm bunch ash) specimen cured for 14 days were also found to higher than that of 28 days curing period at 20% PBA content. The UCS values for 14 days became higher than that at 28 days at 25% PBA content. The PBA can be used as a lateritic soil stabilizer between (20-25%) PBA content.

The study reviewed is related to the present study because its determine the compressive strength of stabilized laterite soil, while the present study also determine and the compressive strength of compressed laterite brick, The study also uses palm bunch ash as agricultural waste and the present study also uses palm leaf ash and palm kernel fibre as agricultural waste. The study differs, as its on investigation of the impact of palm bunch ash on the stabilization of poor lateritic soil while the present study is on comparative analysis of compressed laterite brick stabilized with palm kernel fiber and palm leaf ash.

Sallehan *et al.* (2011) Conducted a study on Properties of laterite Brick with Oil Palm Empty Fruit Bunch Fibres in Department of Building, Faculty of Architecture, Planning &Surveying, Universiti Teknologi MARA, Seri Iskandar Campus,32610 Seri Iskandar, Perak, Malaysia and Department of Building, Faculty of Architecture, Planning &Surveying, Universiti Teknologi MARA Malaysia, The main aim of the research was to study the physical and mechanical properties of laterite brick reinforced with OPEFB fibre, including dimensions, weight, density, water absorption and compressive strength. The tests were carried out according to BS 3921:1985 for water absorption and compressive strength tests.

The mix proportion of the control bricks was 70% soil, 24% sand, and 6% cement. Meanwhile, the OPEFB fibre contents ranged from 1% to 5% by weight of cement. The specimens were taken from a total of 120 bricks. The findings withdrawn from the research were: firstly, the density of laterite bricks was decreased with the increase in the OPEFB fibre content of the bricks. Secondly, it was found that the addition of the OPEFB fibres improved the compressive strength of the bricks, and the maximum compressive strength determined in this study for bricks was with 3% fibre content. Finally, the water absorption results indicated a small increase in water absorption with the increase in the OPEFB fibre content in laterite bricks.

All the materials used in this specimen were local products that had been supplied by local manufactures except cement. The materials that were used to produce brick specimens were laterite soil, sand, cements and OPEFB fibres.

The study reviewed is related to the present study because it determined the specific gravity and moisture content and compressive strength of laterite brick while the present study is also design to determine and compare the compressive strength and moisture content of laterite Bricks stabilized with palm kernel fibre and palm leaf ash. The study differs in objectives and geographical location.

Abdullah *et al.* (2016) carried out a study on the Strength and Absorption Rate of Compressed Stabilized Earth Bricks (CSEBs) Due to Different Mixture Ratios and Degree of Compaction. Compressed Stabilized Earth Brick (CSEB) was produced by compressing a mixture of water with three main materials such as Ordinary Portland Cement (OPC), soil, and sand. The study focuses on laterite soil taken from the surrounding local area in Parit Raja, Johor, and CSEB samples are produced based on prototype brick size 100×50×30 mm. The investigations are based on four different degree of compactions (i.e. 1500, 2000, 2500, and 3000 Psi) and three different mix proportion ratios of cement: sand: laterite soil (i.e. 1:1:9, 1:2:8, 1:3:7). A total of 144 CSEB samples have was tested at 7 and 28 days curing periods to determine the compressive strength (BS 3921:1985) and water absorption rate (MS 76:1972). It was found that maximum compressive strength of CSEB was 14.68 N/mm2 for mixture ratio of 1:3:7 at 2500 Psi compaction. Whereas, the minimum strength is 6.87 N/mm^2 for 1:1:9mixture ratio at 1500 Psi. Meanwhile, the lowest water absorption was 12.35% for mixture ratio of 1:2:8 at 3000 Psi; while the 1:1:9 mixture ratio at 1500 Psi gave the highest rate of 16.81%. This study affirms that the sand content in the mixture and the degree of compaction would affect the value of compressive strength and water absorption of CSEB37.

The study reviewed is related to the present study because its determine compressive strength stabilized laterite soil while the present study also determine and compare the compressive strength of laterite brick stabilized with some agricultural waste. There is differences in objective and geographical location.

Waziri, (2013) conducted a study of Properties Compressed Stabilized Earth Blocks (CSEB) For Low-Cost Housing Construction. The study investigates the suitability of stabilized laterite soils for the production of compressed earth blocks for low-cost housing construction. Soil samples for the experiment were obtained at two different locations. Sample I was obtained at a borrow pit along Gujba road in Damaturu Yobe state while Sample II was taken at a borrow pit near lake Alau in Borno sate, Nigeria. The results of the study revealed that the specific gravity, bulk density, moisture content and plasticity index of both samples showed satisfactory performance. Different cement stabilization levels of 0%, 2.5%, 5% and 7.5% were used to prepare the specimens for testing. The blocks were moulded using hand operated CINVA-Ram machine. The maximum compressive strength of 2.48N/mm2 was obtained with stabilization level of 7.5% with sample I at 28 days curing. The strength of the specimens increases with increasing cement content with an average value of 0.35N/mm2. For higher strength requirements different stabilization options can be considered

The study reviewed is related to the present study because its determine compressive strength stabilized laterite soil while the present study also determine and compare the compressive strength of laterite brick stabilized with some agricultural waste. There are differences in objective and geographical location.

Hassan *et al.* (2020) carried out a study on the Performance of CSEB Block alternative to Brick in the context of Bangladesh This study experiment the probability of using CSEB as interior and exterior partition wall. CSEB made of dredged sand and stabilized by Ordinary Portland Cement (OPC). The aim of the experiment is to find out the optimum percentage of cement stabilizer. Different ratio of cement mix with dredged sand proved to be viable options for economical and durable blocks. Different ratios of cement-sand (1:4, 1:5 and 1:6) were tested for three days, seven days and twenty eight days. The observations on different ratios of cement-sand and change of strength with maturity age showed that each composition has its own quality on particular area. It is found that 1:6 cement-sand block gives satisfactory result in terms of durability and strength.

The study is similar to the present study because its try to improve the quality of compressive stabilized earth brick by determining the compressive strength and water absorbance rate of brick. While present also seek to improve the quality of compressive earth brick using some agricultural waste and determine the compressive strength and water absorbance rate of brick. The study differs in objectives and geographical location.

2.3 Summary of the Literature Review

The literature reviewed revealed the high cost of building materials which poses a significant threat to both the construction industry and people aspiring to own houses, it also confirmed that many building projects were not completed on time due to the cost of materials, which have been on the increase.

The literature reviewed shows that Laterite is a weathered material composed principally of iron oxides, aluminum, titanium and manganese, and is classified as a soft porous earthy soil; often found 15 cm below the top soil. The structural patterns of literite soils exhibit great variability in relation to the shape and size of the elements.

The literature reviewed further revealed that palm kernel fibre is a waste gotten from the extraction of palm oil from the kernel disposed after the content is used. These wastes possess a great environmental degradation that usually results in pollutions, blocking of water channels and in most cases to outbreak of disease. Palm Leaf Ash have being known to be competent binder in enhancing mortar and concrete properties. Palm ash is found to have great potential and it may be effectively utilized as construction material in reducing the CO_2 emission into the atmosphere and minimizing the cost of construction without compromising the service life of the structures.

The literature reviewed showed that Compressed Earth Bricks (CEBs) are masonry elements, which are small in size with regular and verified characteristics obtained by the static or dynamic compression of earth in a humid state followed by immediate demolding.

The literature reviewed also revealed that sieve analysis is a grading by size of particles of powdered or granulated material done with a sieve. Sieve analysis is a commonly used and most often the only practice to determine size distribution of grained materials. While the specific gravity is the ratio of the density of a substance to the density of a reference substance; equivalently, it is the ratio of the mass of a substance to the mass of a reference substance for the same given volume. Specific gravity test is done to measure the strength or quality of the material. The literature reviewed shows that water penetration test a method to assess the resistance to rain water penetration**.**

Water penetration into brick masonry walls leads to several problems such as efflorescence, mortar joint deterioration, interior moisture damages and spalling.

The literature reviewed shows that the durability of a brick is determined by abrasion resistance test, abrasion resistance test is a test method that measure the relative abrasion resistance of standard conditions at room temperature.

The literature reviewed has also shown some research studies on the effect of compressed earth bricks which is recommended for use in some developing countries like Nigeria, In all the studies so far reviewed, there is ample evidence that there is no study on comparative effects of the characteristics properties of compressed literite earth brick stabilized with palm leaf ash and palm kernel febre. Hence this study focused on comparative effect of characteristic properties of compressed laterite brick stabilized with palm kernel fibre and palm leaf ash.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Research Design

The study adopted experimental Research design. According to Patrick (2015) experimental Research design is the blue print of procedure which enables the researcher to test hypothesis by reaching valid conclusions about relationship between dependent and independent variables. Experimental research is a scientific approach to research, where one or more independent variables are manipulated and applied to one or more dependent variables to measure their effect on the latter (Formplus Blog Jan23).

A true experiment is a type of experimental design is thought to be the most accurate type of experimental research. A true experiment is also thought to be the only experimental design that can establish cause and effect relationships (Yolanda, 2015).

This research design was adopted for the study to provide experimental evidence that determined and compared the effects of the characteristics properties of compressed laterite earth brick stabilized with palm leaf ash and palm kernel fibre.

3.2 Area of the Study

The study was carried out in Bida local government headquater. Niger State of Nigeria. Bida is located at latitude 9.083333 and longitude 6.016667 with coordinate of 9.4 59.9988 N. and 10.0012 E. The sample and material were collected within bida local government of Niger State and was tested in the laboratory of Building Technology Department, Federal polytechnic Bida Niger State. The study was carried out in Bida because of the gross deficit in house ownership in Bida and availability of laterite soil together with palm tree within the area.

3.3 Apparatus and Materials to be used for the Study

The materials used for the research work are: Laterite, palm kernel fibre, palm leaf ash and water.

1 Laterite is a consolidated product of humid tropical weathering predominantly composed of goethite, hematite, kaolin, quartz, bauxite and other clay minerals. The laterite was obtained at about 6km (north-west) away from Federal Polytechnic Bida.

2 Palm kernel fibre is a by-product of the extraction of palm oil from palm fruits. The palm kernel fibre used was obtained from pichi which is about 6km (north-west) away from Bida.

3 Palm leaf ash is a burnt product of palm tree branch. . The palm leaf ash used was obtained from pichi, pichi is a name of village that is about 6km away from Bida.

4 The available water in the polytechnic was used.

The instruments that were used are: weighing balance, shovel, manual press machine, sieves, crushing machine, curing devices, taping rod, wheel barrow, wire brush and water tank.

1. Weighing balance was used to weigh the materials.
2. Shovel is was used to mixed the laterite and convey it to the manual press machine.
3. Manual press machine is was used to mold the bricks.
4. Sieves was used to separate the grades of the laterite.
5. Crushing machine was used to determine the compressive strength of the bricks nylon was used to keep the bricks samples under a controlled temperature.
6. Taping rod was used to tap the mould after it has been filled with laterite.
7. Wheel barrow was used to convey the bricks to where crushing machine is fixed.
8. Water sprayer with tank was used for water penetration test.
9. Sieves

10. Balance

11. Rubber pestle and mortar

12. Sieve shaker

13. Wire mesh

3.4 Instrument for Data Collection

3.4.1 Instrument for specific gravity test

The density bottle and weighing scale machine was used to test the specific gravity of the laterite. These were available at the Building Technology Department, Federal Polytechnic Bida Niger State.

3.4.2 Instrument for sieve analysis

1. sieve
2. shaker
3. hammer
4. head pan
5. Weighing scale

3.4.3 Instrument for compressed stabilized laterite brick test

The compressive strength test machine at the Building Technology Department, Federal Polytechnic Bida Niger State was used to crush the bricks samples in order to determine their compressive strength.

3.4.4 Instrument for water penetration rate test

The weighing scale machine and water sprayer available at the Building Technology Department, Federal Polytechnic Bida Niger State was used to weigh the bricks samples in order to determine their water penetration rate.

3.5 Experimental Procedures for the Study

3.5.1 Procedure for specific gravity test on laterite

The following are the procedures for the specific gravity test of the laterite sample:

1. The laterite sample was dried thoroughly and free of moist
2. Empty weighing bottle was weighed, the weight was coded as w1.
3. The empty bottle was filled with 1/3 of laterite, weighed and coded as W2.
4. Density bottle was filled with $1/3^{rd}$ capacity with laterite and with full water, weighed and coded as W3.
5. Density bottle was filled with clean water, weighed and coded as W4.

3.5.2 Procedures for sieve analysis of the laterite sample

1. The following sieve size 475mm, 2.36mm, 1.18mm, 425um, 300um, 150mm, and 75um stack was placed without the sample material in the sieve shaker.

2. The representative sampleof 600g was poured into the top sieve of the sieve stack.

3. The sample was poured as evenly as possible on the surface of the top sieve.

4. Machine was turned on and timer was also set. Once the sieve shaker has finished its cycle, it turned itself off automatically (Malewski, 2017)

3.5.3 Preparation of laterite samples

The laterite samples was air–dried for seven days in a cool, dry place. Air drying was necessary to enhance grinding and sieving of the laterite. After drying, grinding was carried out using a punner and hammer to break the lumps present in the soil. Sieving was done to remove over size materials from the laterite samples using a wire mesh screen with aperture of about 6mm in diameter as recommended by Raheem *et.al* (2012). Fine materials passing through the sieve was collected for use while those retained will be discarded.

3.5.4 Procedures for Mixing Laterite, Palm Kernel Fibre and palm leaf ash

1. Laterite of 101.64g and palm kernel fibre of 1.02g for 1% stabilization, 2.04g, for 2% stabilization, 3.06g for 3% stabilization was measured

2. The measured laterite and palm kernel fibre was mixed together thoroughly using water.

3. Laterite of 101.64g and palm leaf ash of 5.08g for 5% stabilization, 10.16g, for 10% stabilization, 15.25g for 15% stabilization was measured

4. The measured laterite and palm leaf ash was mixed together thoroughly using water.

3.5.5 Procedures for molding compressed stabilized laterite brick

1. The mold of manual press machine was cleaned and oil to reduce friction and easy remover.
2. The mold was filled with the laterite and compacted using taping rod.
3. The mold was press down manually for maximum compression
4. The mold was press up manually to enable easy removal of the brick

3.5.6 Procedures for curing compressed stabilized laterite brick

1. Bricks was kept close to each other to avoid rapid drying.
2. Nylon was used to cover the bricks.

3.5.7 Procedures for testing compressive strength of compressed stabilized laterite brick

The compressive strength test machine was used for this test. The compressed stabilizes laterite Brick samples was crushed on the 7, 14, 21 and 28 days after their production. The bearing surface of the compressive strength testing machine was cleaned very well, a brick sample was placed appropriately on the machine, the machine to crushed the brick sample gradually as a careful observation is being made. As soon as the brick is crushed the machine was stoped and the reading was taken, the crushed sample was removed. The procedure was replicated until all the samples were crushed.

3.5.8 Procedure for water penetration test of compressed stabilized laterite brick

1. The brick samples was weighed and noted (M1)

2. The weighed samples were sprayed with water for 6 hours (considering duration of rainfall in bida).

3. The weight of the wet brick samples were taken and noted as (M2)

4. The weight m1 and M2 was calculated to get water penetration rate.

3.5.9 Procedure for durability test of compressed stabilized laterite brick

The durability of the bricks was determined through abrasive test after the compressed laterite bricks have attained the specified age:

1. The bricks were weighed and their weight recorded as M1.

2. The bricks were placed on a smooth and firm surface and then wire-brushed to and fro on all the surfaces for 60 times, to and fro making a stroke.

3. The bricks were weighed again and recorded as M2 to determine the amount of material or particles abraded. This procedure was repeated for all bricks produced at various PKF and PLA contents.

3.6 Validity of Instrument

Sieve, Density bottle, weighing scale machine, Compressive strength test machine and wire brush are conventional instrument used to measure the compressive strength of bricks, determine the right size of laterite sample, determine the quality of laterite sample, determine the specific gravity of a material, determine the durability of the brick. In order to obtain the validity of these instruments, Two experts from Building Department, Federal Polytechnic Bida and one expert from civil Engineering Department, Federal

Polytechnic Bida, Attest to the validity of these instruments using the manufacturing manual of such machines.

3.7 Reliability of Instrument

The Sieve, weighing balance and compressive testing are reliable standard industrial machines base on their manufacturer manual meant for their specific purposes, the instruments were design by standard technological industries for use in the laboratory to determine the physical properties of materials and for testing their strength and performance. Since the instruments are standardized industrial machines used for their purposes, information from the manual certified that the machines were designed and produced as per British standard and loading with accurate and reliable test data, with reliability of ±0.5.

3.8 Method of Data Collection

The data was collected by computing the results from the test conducted on the materials. For sieve analysis the weight of each sieve size were recorded in a table. To ascertained the specific gravity of the laterite, the weights of the Empty bottle w1, the empty bottle filled with 1/3 of laterite W2, bottle filled with $1/3^{rd}$ capacity with laterite and with full water W3 and bottle filled with clean water W4 were recorded in table. For the strength of compressive stabilized laterite brick, three sample bricks (fiber and ash) of each percentage were crushed and the readings were recorded directly from the crushing machine. For the resistance to abrasion, three sample bricks (fiber and ash) of each percentage were wired brushed and weighed using weighing scale and the results were recorded for computation. And for water penetration rate, three sample bricks (fiber and ash) of each percentage were sprayed and weighed using weighing scale and the results was recorded for computation.

3.9 Method of Data Analysis

The results that were obtained directly from the samples of respective test and computation with appropriate formula was used to answer research question one, two, three, four and five. For each material that was tested that is laterite, compressed laterite brick stabilized with palm kernel fibre and compressed laterite brick stabilized with palm leaf ash.

To carryout the sieve analysis of the laterite.

1. Mass retained on each sieve and the pan was weighed
2. Results was organized in table which provides columns sieve number, sieve size, and mass fraction retained

To obtained the Specific Gravity of laterite

Jones (2018) expressed the specific gravity of any material used for building construction as : $\frac{(W2-W1)}{(W4-W1)-(W3-W2)}$. This was used to compute the specific gravity

W_1 is the weight of the empty density bottle which was 185g.

W_2 is the weight of density bottle with 1/3 of laterite sample which was 385g

W_3 is the weight of density bottle with 1/3 of laterite sample and water density bottle. Which was 887g

W_4 is the weight of density bottle with clean water which was 759g

$$SG = \frac{(W2-W1)}{(W4-W1)-(W3-W2)}$$

$$= \frac{(385-185)}{(759-185)-(887-385)}$$

$$= \frac{200}{(574)-(502)}$$

$$= \frac{200}{(72)}$$

= 2.78g

To determine compressive strength.

Compressive strength/ crushing strength of brick test was calculated by using the compressive strength formular, F= P/A.

Where, F= Compressive strength of the brick (in N/mm2),

P= Maximum load applied to the brick (in N) and

A= Cross sectional area of the specimen (in mm2)

The result of 28th days bricks of palm leaf ash stabilized brick and palm kernel fiber stabilized brick was compared

To determine water penetration rate of Compressed Stabilized Laterite Brick

The water absorption rate formula was adopted

Water penetration $=\frac{m_1-m_2}{M_1} \times 100$. Where:

M_1= weight of the dried brick

M_2= weight of the wet brick

The result of percentage of palm leaf ash stabilized brick and palm kernel fiber stabilized brick was compared, And the bricks stabilized with PLA has better resistance.

To determine durability Compressed Stabilized Laterite Brick

Abrasion resistance formula was used

Abrasion resistance $= \frac{M_2-M_1}{M_1} \times 100$. Where:

M_1= weight of the brick before abrasion

M_2= weight of the brick after abrasion

The result of percentage of palm leaf ash stabilized brick and palm kernel fiber stabilized brick was compared, And the bricks stabilized with PKF has better resistance

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Research Question One

What is the sieve analysis of the laterite sample used for the production of Compressed Stabilized Laterite Earth Brick?

The results analyzed for research question one are presented in table 4.1.

Table 4.1: The results of the sieve analysis of the laterite sample used for the production of Compressed Stabilized Laterite Earth Brick

Sieve size	Empty sieve (g)	Weight retained (g)	Cumulative Percentage % retained	Cumulative % passing
4.75mm	5	0.84	99.16	0.84
2.36mm	6	1.01	98.15	1.85
1.18mm	28	4.71	93.44	6.56
425μm	195	33.12	60.32	39.68
300 μm	255	42.86	17.46	82.54
150 μm	89	14.96	2.50	97.50
75 μm	10	1.68	0.82	99.50
Pan	4.88	0.82	0	0
Total	592.88	100		

Table 4.1 shows the sieve analysis of laterite sample. The percentage of material passing through 425um sieve is 39.68%. of the sample used for the production of compressed laterite brick. The sample is considered to be suitable for sub-grade, sub-base and base materials as the percentage by weight finer than 425um grit size is less than 40%.

4.2 Research Question Two

What is the specific gravity of the laterite sample used for the production of Compressed Stabilized Laterite Earth Brick?

The results analyzed for research question two are presented in table 4.2.

Table 4.2: The Results of the Specific Gravity of The Laterite Sample used for the Production of Compressed Stabilized Laterite Earth Brick

No. of trials	T1	T2
Mass of bottle + plate W1	185	182
Mass of bottle + soil + plate W2	385	383
Mass of bottle + soil + plate + water W3	887	886
Mass of bottle + plate + water W4	759	758
$SG = \frac{W_2-W_1}{(W_4-W_1)-(W_3-W_2)} \times$	2.78	2.75

T1 = First test

T2 = Second test

NIS Specification: The specific gravity of laterite soil ranges between 2.75 to 3.0.

The result of the specific gravity test of laterite soil samples are 2.78 and 2.75 which is within the range of standard specification of NIS and therefor considered good in quality and suitable for the production of compressed laterite Earth bricks.

4.3 Research Question Three

What is the compressive strength effect of Compressed Stabilized Laterite Earth Brick Stabilized with Palm Kernel Fibres and Palm Leaf Ash?

The results analyzed for research question three are presented in table 4.3.

Table 4.3 The results of compressive strength test of Compressed Stabilized Laterite Earth Brick Stabilized with Palm Kernel Fibre

Percentage (%)	Days	No. Bricks	Average (Kg)	CS (KN/m^2)
1	7	3	70663	2.89
	14	3	58963	2.41
	21	3	51673	2.11
	28	**3**	**49363**	**2.02**
2	7	3	76820	3.15
	14	3	71633	2.93
	21	3	67243	2.75
	28	**3**	**50493**	**2.07**
3	7	3	84713	3.47
	14	3	80513	3.3
	21	3	67887	2.8
	28	**3**	**55290**	**2.26**

Key: CS = Compressive Strength

The result in table 4.3 of laboratory test revealed that compressive strength of bricks stabilized with Palm Kernel fiber (PKF) at 1% for 7 days, 14 days 21 days and 28 days to be 2.89N/mm^2, 2.41N/mm^2, 2.11Nmm^2, and 2.02N/mm^2. The result further revealed that the bricks stabilized PKF at 2% have 3.15N/mm^2 at 7 days, 2.93N/mm^2 14 days, 2.75N/mm^2 21 days, and 2.07N/mm^2 28days. And the bricks stabilized at 3% have compressive strength of 3.47Nmm^2 at 7 days, 3.30Nmm^2 at 14 days, 2.80Nmm^2 at 21 days and 2.26Nmm^2 at 28 days (See details in Appendix C, 77).

These results of compressive strength showed that all the bricks conformed with the NBRRI specification.

The results analyzed for research question three are presented in table 4.4.

Table 4.4 The results of compressive strength test of Compressed Stabilized Laterite Earth Brick Stabilized with Palm Leaf Ash.

Percentage (%)	Days	No. Bricks	Average (Kg)	CS (KN/m^2)
5	7	3	36207	1.48
	14	2	39017	1.60
	21	3	40973	1.68
	28	**3**	**41977**	**1.72**
10	7	3	40717	1.67
	14	3	424667	1.73
	21	3	42937	1.76
	28	**3**	**43730**	**1.79**
15	7	3	42367	1.73
	14	3	42603	1.74
	21	3	43920	1.80
	28	**3**	**44317**	**1.81**

The result of the laboratory experiment in table 4.4 revealed the compressive strength of the brick stabilized with Palm Leaf Ash at 5.0% stabilization to be 1.48 Nmm^2 at 7 days, 1.60Nmm^2 at 14 days, 1.68Nmm^2 at 21 days 1.72Nmm^2 at 28 days. The compressive strength of the bricks stabilized with palm leaf ash (PLA) at 10% have 1.67Nmm^2 at 7 days, 1.73Nmm^2 at 14 days, 1.76Nmm^2 at 21 days, and 1.79Nmm^2 at 28 days. The result further revealed the compressive strength of the bricks at 15% stabilization to be 1.73Nmm^2 at 7 days, 1.74Nmm^2 at 14 days, 1.80Nmm^2 and 1.81Nmm^2 at 28 days(See details in Appendix D, 78).

These are in conformity with NBRRI Specification for compressive strength of compressed laterite brick of 1.65 Nmm^2 (Agbede & Manasseh, 2017).

4.4 Research Question Four

What is the water absorption rate test of compressed laterite Brick stabilized with palm kernel Earth fibre and Palm Leaf Ash?

The results analyzed for research question four are presented in table 4.5

Table 4.5 The results of water penetration test of compressed laterite brick stabilized with palm kernel fibre.

N	FIBRE	W1(g)	W2(g)	W3(%)	W4(%)
1		3.42	3.74	9.36	
2	1	3.31	3.71	12.08	10.18
3		3.41	3.72	9.09	
4		3.40	3.75	10.29	
5	2	3.28	3.74	14.02	11.52
6		3.41	3.76	10.26	
7		3.29	3.69	12.16	
8	3	3.34	3.72	11.38	12.19
9		3.30	3.73	13.03	

Key: Fibre= the percent of the PKF, N= Number of the bricks,W1 = Weight of dry brick, W2 = Weight of wet brick, W3= water absorption rate,W4= average water absorption rate.

The result in table 4.5 of laboratory test revealed the average water penetration rate of compressed laterite brick stabilized with palm kernel fiber stabilization is 10.18% for 1% stabilization, 11.52 for 2% stabilization and 12.19% for 3% stabilization.

These result showed that 1%, 2% and 3% stabilization are in conformity with NBRRI specification.

The results analyzed for research question four are presented in table 4.6.

Table 4.6 The results of water penetration test of compressed laterite brick stabilized with palm leaf ash.

N	ASH	W1(kg)	W2(kg)	w3 (%)	W4 (%)
1		3.32	3.64	9.64	
2	5	3.29	3.69	12.16	11.58
3		3.32	3.75	12.95	
4		3.30	3.65	10.60	
5	10	3.23	3.60	11.46	10.63
6		3.31	3.64	9.97	
7		3.28	3.65	11.28	
8	15	3.25	3.57	9.85	10.27
9		3.31	3.63	9.67	

Key:
Ash= the percent of the PLA, N= Number of the bricks W1 = Weight of dry brick, W2 = Weight of wet brick, W3= water absorption rate,W4= average water absorption rate.

Table 4.6 showed the laboratory test result of Water absorption rate of compressed laterite brick stabilized with palm leaf ash to be 11.58 at 5% stabilization, 10.63% at 10% stabilization, and 10.27% at 15% stabilization.

all the bricks are in conformity with NBRRI specification of 12.5%.

4.5 Research Question Five

What is the resistance abrasion effect of Compressed Stabilized Laterite Earth Brick Stabilized with Palm Kernel Fibre and Palm Leaf Ash?

The results analyzed for research question five are presented in table 4.7.

Table 4.7 The results of abrasion test of Compressed Stabilized Laterite Brick Stabilized With Palm Kernel Fibre at 28 days.

N	FIBRE	M1(kg)	M2(kg)	M3(%)	M4 (%)
1		3.42	3.37	1.48	
2	1	3.41	3.36	1.49	1.40
3		3.32	3.28	1.22	
4		3.39	3.35	1.19	
5	2	3.49	3.43	1.75	1.27
6		3.40	3.37	0.89	
7		3.45	3.40	1.47	
8	3	3.38	3.32	1.81	1.68
9		3.45	3.39	1.77	

Key: No = Number of the bricks, Fibre = the percentage of PKF M1 = the mas of the brick before abrasion, M2 = the mas of the brick after abrasion, M3 = the abrasion resistance of the brick, M4 = The average of abrasion resistance of the brick.

Table 4.7 shows the laboratory test result of Abrasion resistance of compressed laterite brick stabilized with palm kernel fiber to be 1.40% at 1% stabilization, 1.27% at 2% stabilization, and 1.68% at 3% stabilization.

The abrasion resistance results falls within the NBRRI specification of 6.9%. The results analyzed for research question five are presented in table 4.1.

Table 4.8 The results of abrasion test of Compressed Stabilized Laterite Earth Brick Stabilized with Palm Leaf Ash At 28 days

No	Ash	M1(g)	M2(g)	M3(%)	M4 (%)
1		3.50	3.43	2.04	
2	5	3.42	3.34	2.40	2.39
3		3.39	3.30	2.73	
4		3.38	3.30	2.42	
5	10	3.35	3.28	2.13	2.22
6		3.37	3.30	2.12	
7		3.40	3.32	2.41	
8	15	3.39	3.31	2.42	
9		3.36	3.29	2.13	2.32

Key: No = Number of the bricks, Ash = the percentage of PLA**,** M1 = the mas of the brick before abrasion, M2 = the mas of the brick after abrasion**,** M3 = the abrasion resistance of the brick**,** M4 = The average of abrasion resistance of the brick.

The result in table 4.8 shows the abrasion resistance of compressed laterite brick stabilized with palm kernel fiber is 2.39% at 5% stabilization, 2.22% at 10% stabilization, and 2.32% at 15% stabilization.

These result shows high abrasion resistance which falls within the NBRRI specification of 6.9%.

4.6 Findings

The following findings were made and are presented in sequential order of the research questions

1. The percentage of the laterite sample that pass through sieve No 425um ranges 39.68% which is in conformity with NBRRI specification

2. The laterite used for the experiment produced specific gravity of 2.78 and 2.75 which falls within the specification of NBRRI of 2.75 to 3.0.
3. Bricks stabilized with palm kernel fiber has compressive strength of 2.02 Nmm^2 at 1%, 2.07 Nmm^2 at 2% and 2.26 Nmm^2 at 3% while the bricks stabilized with palm leaf ash produced compressive strength of 1.72 Nmm^2 at 5%, 1.79 Nmm^2 at 10%, and 1.81 Nmm^2 at 15%. Thus the bricks stabilized with PKF produced higher compressive strength.
4. Bricks stabilized with palm kernel fiber has water penetration rate of 10.18 at 1%, 11.52 at 2% and 12.19 at 3% while the bricks stabilized with palm leaf ash has water penetration rate of 11.58 at 5%, 10.63 at 10% and 11.27 at 15%. This showed that bricks stabilized with PLA produced higher water penetration resistance.
5. Bricks stabilized with palm kernel fiber has abrasion resistance of 1.40 at 1%, 1.27 at 2% and 1.68 at 3% while the bricks stabilized with palm leaf ash has abrasion resistance of 2.39 at 5%, 2.22 at 10% and 2.32 at 15%. This indicated that the bricks stabilized with PKF produced higher abrasion resistance.

4.7 Discussion of Findings

The findings of research question one showed that percentage of laterite material passing through 425um sieve is 39.68%. Sample was used for the production of compressed stabilized laterite brick. These are shown in table 4.1. The sample is considered to be suitable for sub-grade, sub-base and base materials as the percentage by weight finer than N0 4.25 test sieve is less than 40%. Results produced agrees with Tijani *et al.* (2017). who observed that sieve analysis results showed that percentage passing No 200 sieve ranged between 12.4 and 33.6%. are considered suitable for construction material.

The findings of research question two showed that the specific gravity of laterite used for the experiment is 2.78 and 2.75 which falls within the NBRRI specification of 2.75 to

3.0.which indicates that the laterite is of good quality. The results agrees with Owolabi and Aderinola (2014) whose summary of the data obtained from the specific gravity test carried out produced specific gravity of the tested samples between 2.64 and 2.75.

The findings of research question three showed that the compressive strength of compressed laterite brick stabilized with palm kernel fiber is 2.02, 2.07, and 2.26 at 28 days curing. It was observed that the compressive strength of the compressed laterite brick stabilized with palm kernel fiber was reducing as the curing days increases but the compressive strength increases as the percentage of PKF increased.

The results are in conformity with NBRRI standard of 1.65, this indicate that fiber possesses good quality that can improve the compressive strength of compressed laterite brick. This is in line with Raheem *et al.* (2012) that produced and tested lateritic interlocking blocks . The experiments involved the production of 250 × 130 × 220 mm3 interlocking blocks. with laterite samples. The results indicated that all of the stabilized blocks satisfied the minimum 28 day wet compressive strength of 1.65 Nmm^2 recommended by the Nigeria Building and Road Research Institute, Thus, concluded that the compressive strength of the bricks increases as the percentage of fiber increases. Also in line with Osital et al (2019) that investigated the mechanical properties of palm kernel fibre reinforced with a waste water sachet material. From the results obtained, the hardness values of the palm kernel fibre composites increases which is attributed to the increase in the ratio of palm kernel fibre of each sample. In simple comparison with the PKF bricks, the bricks stabilized with palm leaf ash produces compressive strength of 1.72 Nmm^2, 1.79Nmm^2, and 1.81 Nmm^2. it is observed that only the bricks stabilized with 15% of palm leaf ash at 28 days of curing that falls below the specification of NBRRI of 1.65. Therefore, palm leaf ash can be used as stabilizer at 1% and 2% to improve the compressive strength of compressed laterite brick. This is in agreement with

Raheem *et al*. (2012) whose minimum 28 days curing produced compressive strength for 5% cement stabilised blocks of more than 1.60 N/mm^2, as recommended in the National Building Code (2006), was not satisfied by all the blocks. It is also in line with Otunyo *et al.* (2018) who investigated the impact of palm bunch ash (PBA) on the stabilization of poor lateritic soil and find out that the values of the UCS increased as the PBA content in the lateritic soil was increased. These result showed that the bricks stabilized with palm kernel fiber have better compressive strength than the bricks stabilized with palm leaf ash.

The findings of research question four (4) showed that the water penetration rate of the stabilized compressed laterite brick with palm kernel fibre is 10.18, 11.52 and 12.19 which meet the standard specification of NBRRI 12.5% at one, two and three percent stabilization. It was observed that the water absorption rate was decreasing as the percentage of the fiber stabilization increases. This is in agreement with Ugwuishiwu *et al.* (2013) that water absorption increased with fiber content increased

The result of stabilized compressed laterite brick with palm leaf ash is 11.58%, 10.63% and 10.27% which meet the standard specification of NBRRI 12.5%, but the water absorption rate increases as the percentage of palm leaf ash increase. This result was expected because the palm leaf ash binds the laterite particles together and thereby reduces the sizes of the pores through which water could flow into the bricks. This is in line with Raheem et.al (2012) who's results showed that Interlocking blocks produced with Idioro laterite exhibited the lowest percentages of water absorption of 7.62%, 5.23% and 5.01% for blocks with 5%, 10% and 15% cement stabilisation, respectively. This indicated that water penetration decreases with increased percentages of stabilisation. This result showed that palm bricks stabilized with palm leaf ash has better water resistance than the bricks stabilized with palm kernel fiber.

The findings on research question five indicated that the abrasion resistance of the bricks stabilized with palm kernel fibre is 1.40% at 1% stabilization, 1.27% at 2% stabilization, and 1.68% at 3% stabilization. This indicated that, palm kernel fiber is a qualitative stabilizer for compressed laterite brick. There is increase in the abrasion resistance as the percentage of the stabilizer increases stabilization at 3% produced the lowest abrasion resistance of 3.67. meanwhile, 1% ,2% and 3% has high abrasion resistance and are in conformity with the standard specification of NBRRI of 6.9%, This is also in line with Raheem *et al* (2012) who's study showed that the resistance of the blocks to abrasion increases with the addition of the stabilising agent. A high percentage of material was abraded away from laterite interlocking blocks that were not stabilised with cement (the control) while the bricks stabilised with palm leaf ash reduced the abrasion as the percentage of the ash increases but still in conformity with the NIS standard of 6.9. The abrasion resistance of the bricks stabilized with palm leaf ash is 2.39% at 5%, 2.22% at 10% and 2.32% at 15%. The abrasion resistance increases as the percentage of palm leaf ash was increased and the result of each percentage meet the standard specification of NBRRI of 6.9%, this indicate that palm leaf ash can improve the abrasion resistance of compressed laterite brick. This is in line with Olowu *et al.* (2014) who found that Improved Stabilized Lateritic Brick (ISLB) offer resistance to abrasive forces relative to the concentration of the Zycosil Water Solution (ZWS) used in its production; that is, the higher the concentration of ZWS the higher the resistance offered by the brick against abrasive forces. ISLB produced with ZWS of 1:100 have abrasion value of 1.0%, CSLB have abrasion value of 3.0% and AULB have abrasion value of 12%. These result showed that bricks stabilized with palm kernel fibre has better abrasion resistance than bricks stabilized with palm leaf ash.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Based on the study it was concluded that the specific gravity of the laterite used for the production of compressed laterite brick is within the standard range of 2.75 to 3.0 specified specific gravity by NBRRI (2006). Therefore, the laterite considered to be of good quality for production of compressed laterite brick. The percentage of the laterite sample that passed through the sieve No 2.36mm ranges between 12% and 35% and therefore considered to be good quality laterite size for production of compressed laterite brick.

The compressive strength of compressed laterite bricks stabilized with PKF at 1.0%, 2.0% and 3.0% produced high compressive strength compared to NBRRI specification of 1.65Nmm^2. This makes compressed laterite brick stabilized with (PKF) qualitative, accessible and affordable building material. The compressive strength of compressed laterite bricks stabilized with PLA at 5.0%, 10% and 15% are all in conformity NBRRI specification of 1.65Nmm^2. Thus 5.0%, 10% and 15% stabilization can be used for the production of laterite brick stabilization. The water absorption rate of compressed laterite brick stabilized with PKF meet the standard specification of NBRRI of 12.5% except 3% stabilization, therefor the laterite bricks stabilized with PKF at 1.0% and 2.0% can be used for building of house. Compressed laterite brick stabilized with PLA have water absorption rate of 10.58% at 5.0% stabilization, 11.63% at 10% stabilization and 11.27% at 15% stabilization which are in conformity with the standard specification of NBRRI.

The abrasion resistance of compressed laterite brick stabilized with PKF at 1%, 2% and 3% have high abrasion resistance considering NBRRI specification of 6.9. this guaranty the that walls build by compressed laterite bricks stabilized with PKF will be durable there by, reducing the cost of the production. While the abrasion resistance of compressed laterite brick stabilized with PLA at 5.0%, 10% and 15% have high abrasion resistance considering NBRRI specification of 6.9 but lower than the abrasion resistance of the bricks stabilized with PKF.

5.2 Recommendations

Based on the findings and conclusion of the study the following recommendations were made:

1. Building professionals should ensure strict adherence of appropriate stabilization percentage of compressed laterite bricks stabilised with palm kernel fibre at 1% and 2% and 3% to their client especially the low income earners as it is environmental friendly and cheap.
2. The government should make compressed machine available and affordable for the low income earners.
3. Awareness campaign through workshops and social media on the use of compressed laterite bricks stabilised with palm kernel fibre at 1.0%, 2.0%, 3.0% while 5.0% and 10% for palm leaf ash stabilization should be made by stake holders.
4. Building construction industry should focus on the importance of the use of natural alternative building materials such as compressed laterite bricks stabilized with palm kernel fibre and palm leaf ash and the conformity with the specifications of NBRRI.

5.3 Contribution to Knowledge

This study has established that the bricks stabilized with palm kernel fibre and palm kernel ash are suitable for construction of house for low income learners. This study established the conformity of bricks stabilized with palm kernel fiber which has compressive strength of 2.02 Nmm^2 at 1%, 2.07 Nmm^2 at 2% and 2.26 Nmm^2 at 3%, it also has water penetration rate of 10.18 at 1%, 11.52 at 2% and 12.19 at 3% while the bricks stabilized with palm leaf ash produced compressive strength of 1.72 Nmm^2 at 5%, 1.79 Nmm^2 at 10%, and 1.81 Nmm^2 at 15%., And water penetration rate of 11.58 at 5%, 10.63 at 10% and 11.27 at 15%. The bricks stabilized with palm kernel fibre has a higher compressive strength, abrasion resistance. That makes it better than the bricks stabilized with palm leaf ash.

5.4 Suggestions for Further Research

The following are the suggestions for further study

1. Carryout research in the use of other stabilizing materials to produce bricks and other building materials.
2. Investigation on permeability of compressed laterite brick walls.
3. Alternative wall finishes for compressed laterite brick stabilized with palm kernel fibre.

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APPENDIX A

LABORATORY EQUIPMENT

Plate I Sieves used for the experiment

Plate II Compressive strength test machine.

Plate III Water Sprayer

APPENDIX B

LABORATORY ACTIVITIES

Plate IV: Laterite Open Air Dry

Plate V: Sieve lateterite using 5mm net

Plate VI Mixing of the laterite with the additive

Plate VII Moulding of brick with compressed manual machine

Plate VIII Bricks stabilized with PLA

Plate IX Curing of the bricks.

Plate X Weighing the brick

XI Abrasion test of the brick

APPENDIX C

RESULTS OF COMPRESSIVE STRENGTH TEST OF COMPRESSED STABILIZED LATERITE EARTH BRICK STABILIZED WITH PALM KERNEL FIBRE

Percentage (%)	Days	No. Bricks	Area	Load	Average	CS
	7	1	24420	76100		
	7	2	24420	65100		
	7	3	24420	70790	70663	2.89
	14	4	24420	64460		
	14	5	24420	53470		
	14	6	24420	58960	58963	2.41
1	21	7	24420	58720		
	21	8	24420	42330		
	21	9	24420	53970	51673	2.11
	28	10	24420	44030		
	28	11	24420	54700		
	28	12	24420	49360	49363	2.02
	7	13	24420	97800		
	7	14	24420	55840		
	7	15	24420	76820	76820	3.15
	14	16	24420	77450		
	14	17	24420	61000		
	14	18	24420	76450	71633	2.93
2	21	19	24420	69880		
	21	20	24420	72480		
	21	21	24420	59370	67243	2.75
	28	22	24420	53210		
	28	23	24420	47780		
	28	24	24420	50490	50493	2.07
	7	25	24420	67340		
	7	26	24420	97990		
	7	27	24420	88810	84713	3.47
	14	28	24420	80730		
	14	29	24420	79480		
	14	30	24420	81330	80513	3.3
3	21	31	24420	60510		
	21	32	24420	75160		
	21	33	24420	67990	67887	2.8
	28	34	24420	49570		
	28	35	24420	60920		
	28	36	24420	55380	55290	2.26

Key: CS = Compressive Strength

APPENDIX D

RESULTS OF COMPRESSIVE STRENGTH TEST OF COMPRESSED STABILIZED LATERITE EARTH BRICK STABILIZED WITH PALM LEAF ASH

Percentage (%)	Days	No. Bricks	Area	Load	Average	CS
	7	1	24420	39160		
	7	2	24420	38570		
	7	3	24420	30890	36207	1.48
	14	4	24420	40100		
	14	5	24420	38290		
	14	6	24420	40200	39017	1.60
5	21	7	24420	39600		
	21	8	24420	38290		
	21	9	24420	45030	40973	1.68
	28	10	24420	43610		
	28	11	24420	34040		
	28	12	24420	48280	41977	1.72
	7	13	24420	36260		
10	7	14	24420	37890		
	7	15	24420	48000	40717	1.67
	14	16	24420	47500		
	14	17	24420	48730		
	14	18	24420	38170	424667	1.73
	21	19	24420	30210		
10	21	20	24420	41280		
	21	21	24420	57320	42937	1.76
	28	22	24420	41160		
	28	23	24420	38310		
	28	24	24420	51720	43730	1.79
	7	25	24420	47600		
	7	26	24420	40720		
	7	27	24420	38780	42367	1.73
	14	28	24420	46310		
	14	29	24420	38530		
	14	30	24420	42970	42603	1.74
15	21	31	24420	45920		
	21	32	24420	43390		
	21	33	24420	42450	43920	1.80
	28	34	24420	40630		
	28	35	24420	46040		
	28	36	24420	46280	44317	1.81

Key: CS = Compressive Strength