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TECHNIQUES FOR IMPROVING ADOBE BLOCKS FOR CONSTRUCTION OF BUILDINGS IN PLATEAU STATE

By

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CERTIFICATION

Jwasshaka, Shirka Kassam a Postgraduate Student of the Department of Vocational Teacher Education, Faculty of Education with Registration number **PG/MED/08/48943** forwards this in partial fulfilment of the requirement for the award of Degree of Master of Education in Industrial Technical Education (Building Option). I affirm that the work is academically original, independent and has not been submitted in part or in full for any other diploma or degree of any University.

…………………	…………………...
Dr. E.O Anaele	**Prof. C.A Igbo**
(Supervisor)	Head of Department

DEDICATION

This piece of work is dedicated to my Late Brother Monday Kassam Jwasshaka whose concern was on the moral and academic upbringing of my life.

ACKNOWLEDGEMENTS

I am indebted to my supervisor Dr. E.O Anaele who in spite of his tight schedules painstakingly read every bit of this work in an attempt to make it original and qualitative for academic purpose. Worth commendation is my Reader Dr. E.O. Ede for his academic contributions in putting the work on the right tract.

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Encouragement of the former and the Present Heads of Department Prof. C.A Igbo and Prof. (Mrs) C.A Obi respectively in my academic pursuit is highly commendable. Indeed, they are source of inspiration to me. God bless you. I appreciate all the wonderful lecturers of the department for their efforts in making sure quality work is carried out through their patience in scrutinizing every line of this work during the monthly departmental proposal.

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The contribution of my course mates during seminars paper presentation, brain storming during leisure time which forms parts of this study cannot go unnoticed. Continue in this spirit for the next tasks ahead. God bless you all.

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Thank you all.

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ABSTRACT

The two important areas in the housing sector are the promotion of building material units using local materials consistent with ecological balance, and the production of building materials with low energy inputs which substitute for energy intensive building materials. Common burnt clay bricks are increasingly becoming costly due to excessive cost of fuel to burn them and not many suitable brick earths are found everywhere. Stabilized adobe block could be an economic alternative to the traditional brick. This study attempted to use cow dung and digitaria exilis straw as stabilizing agent for adobe to find out whether there is a significant improvement in strengths for use in construction of buildings in Plateau State. The main focus of the study was to determine its compressive, shear, tensile strengths and water absorption of the specimen produced. 280 samples at mix proportions of (1:3 and 1:4) of digitaria exilis to adobe and cow dung to adobe respectively were produced and subjected to a curing periods of 28 days after which they were subjected to laboratory tests. The results showed that the blocks produced from both additives at specified ratios were poor in shear and tensile strength. However, adobe blocks produced from mixture of digitaria exilis straw and cow dung at mix proportions of 1:4 and 1:3 respectively indicates an acceptable strength and has low water absorption which complied with the British Standard. Hence could be recommended for Non Load bearing walls and for construction of walls that are prone to water erosion.

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CHAPTER I

INTRODUCTION

Background of the Study

Man has three basic needs, which are food, shelter and clothing. All efforts for technological advancement are hinged on to satisfying these basic needs. However, housing is the most difficult and expensive to provide. According to Agarwal (1981) the difficulty in the provision of housing is as a result of high cost of building materials. Though the advent of cement has revolutionized building construction activities, Barry (2005) observed that the cost of building materials is still on the increase. Badejo (2002) and Yusuf (2005) also observed that the cost of cement has continued to rise thereby making the cost of walling materials and building to rise also. Effort is being made to use alternative to cement to tackle the problem of high cost of walling materials for building. Emphasis is given to the maximum use of locally available materials such as adobe.

Martin (1995) described adobe as a naturally occurring material composed primarily of fine or coarse grained soils which is generally plastic at appropriate water contents and will harden when dried or fired. Adobe could also mean walling materials which consist of clay-loam soil puddle with water, sometimes, containing straw. According to Minke (2000) blocks of earth produced manually by throwing wet earth into a framework are called adobes or mud bricks or sometimes sundried earth blocks.

The conventional method of using adobe for construction in Plateau State does not make wall construction durable to withstand whether effects. This practice is usually done by trial-and-error. Continuous application of this traditional method has resulted to washing down of the wall surface by rain and eventually causing total collapse of the building. Constant maintenance of the wall surface being washed down by rain is also the resultant effects of this old method. Worried by this ugly consequence, new technique could be developed to improve the strength of adobe for more durable wall construction.

An alternative way to realize the target of building quality, low-cost and affordable decent shelter for Nigerians as stated in the Nigeria "country profile" to the United Nations in 1997 and in the National Economic Empowerment and Development Strategies (NEEDS) documents (2004) include developing cheaper building materials that are locally obtainable. The effort of this document is geared towards intensifying on the need of using local raw materials, such as cement-stabilized laterite and burnt bricks, to reduce the cost of housing construction. The NEEDS document also emphasizes that the Faculties of Architecture and Building at Tertiary Institutions will be encouraged to teach their students to design and build with low- cost, local materials. Such development of materials must also take into account sustainability and environmental friendliness without compromising quality and standard of modern construction as observed by Dowlings (2004). One of such approaches is the use of adobe for building houses.

According to Naizi (1998) in order to use adobe as a viable alternative sustainable building material, measures must be taken to overcome known weaknesses of the earth material. There is therefore need for a concerted effort to improve the weaknesses of adobe associated with the stability, water-proofing quality and resistance to erosion by rain. Local Builders in Plateau State lack such technique of improving the strength of adobe as a major local building material. It is expected that by improving adobe, the developing countries can actually move ahead towards the evolution of a truly indigenous technology and appropriate construction materials which will be available and affordable to all for achieving their housing needs.

A technique is a methods, ways or measures newly adopted or taken to address a situation. Technique means a practical method or art applied to some practical task (http://www. Audioenglish.net/dictionary/technique.Htm). In the context of this study, technique means applying a method through scientific means to improve the strength of adobe blocks using additives like cow dung and digitaria exilis.

Statement of the Problem

The cost of building materials especially walling materials in Nigeria is very high. This has made people to use other alternative materials like

Bamboo, Stones, Clay product, and Wood which are dependable and not quite expensive to acquire.

Adobe is a popular and common material used for walling in Plateau State, as a traditional building material. It has a number of shortcomings. Adobe is prone to fire hazards and attack by termites, it does not withstand weather effects, often, rainstorms causes a lot of damage to the adobe walls thereby requiring seasonal maintenance which consume time and labour. It is weak and has problems not desired for use as walling material. In agreement to this, Shehu (2002) observed that natural disasters such as flood during the rainy season also affect adobe building in rural and even in some semi-urban buildings particularly at the mid of the rainy season when excess water is released

Adobe walls have the problem of cracking due to drying shrinkage, high rate of water absorption which leads to many houses collapsing during heavy rain fall, Rodents boring holes easily in the walls, low compressive, tensile and shear strength. These problems have made building with adobe walls not strong, durable and have led to the collapse of many buildings especially during heavy rain, killing and maiming the occupants as well as lost of property. Because of these problems posed by the traditional method of utilizing adobe and with the increase in demand for housing, the traditional building system has not satisfied the need for adequate building materials and techniques for construction in Plateau State. Hence, the challenge for the study to determine the technique to improve adobe blocks used for building construction in the State.

Purpose of the Study

The main purpose of the study was to determine the technique for improving adobe block for construction of buildings in Plateau State. Specifically, the study determines:

1. The mix ratios of cow dung to adobe and digitaria exilis to adobe that adobe block will give optimal compressive, shear and tensile strength and water resistance for building purpose.
2. The compressive strength of adobe block mixed with cow dung and adobe block mixed with digitaria exilis straw (Acha).
3. The tensile strength of adobe block mixed with cow dung and adobe block mixed with digitaria exilis straw (Acha).
4. The shear strength of adobe block mixed with cow dung and adobe block mixed with digitaria exilis straw (Acha).
5. The water absorption rate of adobe block mixed with cow dung and adobe block mixed with digitaria exilis straw (Acha).

Significance of the Study

The study would be of benefit to many individuals and groups, including building technology teachers and students, Entrepreneurs, the Society, and Professional bodies in the building construction industries.

The findings of this study will provide Building Technology Teachers with adequate information concerning the standard mix ratios on how to produce blocks from the mixture of Laterite with cow dung and with digitaria exilis at cheaper or no cost for students practical. Entrepreneurs would use the findings of the study taking advantage of its strength for mass production to venture into small scale businesses and also as a means for wealth creation.

The findings of the study would help the individuals produce more durable alternative blocks for building affordable, strong, and durable houses for the society members. The society would also heave a sigh of relief as a result of the findings of the study as a new discovery and would feel relief from the frequent collapse and maintenance of buildings, thereby saving lives and property. A new horizon would be opened in the area of job creation for the unemployed as a result of the findings of this research work because many people would desire to venture into its production for commercial purposes.

The communities would re-discover more alternative construction materials using available materials within their domain as a result of the findings of this study. This would help reduce over dependency on Sandcrete blocks which is not within the reach of the low- income earners due to high cost of Cement and its constituents.

The findings of the study would be beneficial as it would provide adobe builders and prospective adobe-building owners with a standardized mix proportion of cow dung to adobe and digitaria exilis to adobe as additives thereby allowing them optimize their use to improve on the safety of adobe buildings base on these standard mix ratios.

The findings of the study would provide standard mix ratios to adobe builders thereby eliminating trial-and-error in the determination of the mix proportions of adobe as being practiced and the accompanying technical lapses from which would normally affect the structural quality of the adobe buildings.

Research Questions

The following five research questions were formulated in line with the purpose of the study to guide the study;

1. At what mix ratios of cow dung to adobe and Digitaria exilis to adobe will Adobe block give optimal compressive, shear and tensile strength, and water resistance for building purpose?
2. What is the compressive strength of adobe block mixed with cow dung and adobe block mixed with Digitaria Exilis straw (Acha)?
3. What is the tensile strength of adobe block mixed with cow dung and adobe blocks mixed with Digitaria Exilis straw (Acha)?
4. What is the shear strength of adobe block mixed with cow dung and adobe block mixed with Digitaria Exilis straw (Acha)?
5. What is the water absorption rate of adobe block mixed with cow dung and adobe block mixed with Digitaria Exilis straw (Acha)?

Delimitation of the Study

The study is delimited to compressive, shear, tensile strengths and water absorption rate of adobe blocks for wall construction in Plateau State. It is also delimited to cow dung and Digitaria Exilis straw as an additive to adobe. This is so because in the past adobe blocks are produced with no consideration to any mixed ratio.

CHAPTER II

REVIEW OF RELATED LITERATURE

The related literature for the study has been reviewed under the following sub-headings:

1. **Conceptual Framework**

- History of Building Construction in Plateau State.
- Adobe as Material for Building Construction in Plateau State
- Compressive Strength of Sandcrete blocks
- Tensile Strength of Sandcrete blocks
- Shear Strength of Sandcrete blocks
- Mix Ratios of Sandcrete blocks
- Water Absorption Rate of Adobe Blocks.
- Cow dung as an Additive for Improving Adobe Blocks
- Adobe as a Building Material, Digitaria Exilis Straw (Acha) as an additive.
- Laterite Soils and its properties
- History of Traditional Techniques of Adobe Construction
- Socio-economic and Environmental Reasons for Alternative materials

2. **Review of Related Empirical Studies.**
3. **Summary of Review of Related Literature.**

Conceptual Framework

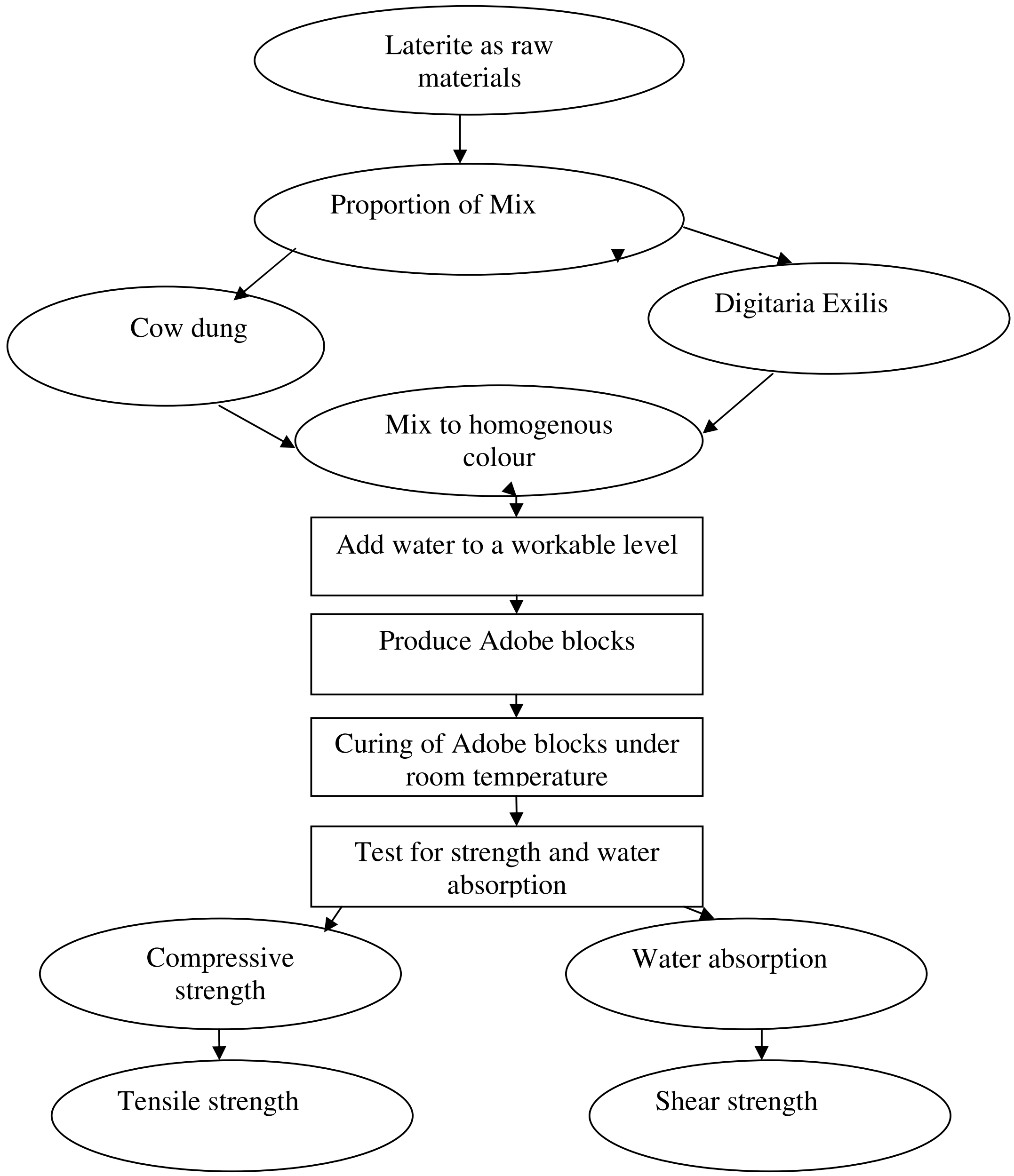

Figure 1. Conceptual Framework of Technique for improving adobe blocks

Conceptual Framework

As aspiration to higher living standards rise, so do the demands for quality low-cost housing grow even more rapidly (Oruwari, Jev & Owei, 2002). Soil as a major construction material to satisfy this demand, needs to be improved because the soil (earth) material as found in its natural state is not durable for long term use in building (North, 1997; Kerali, 2001). By modifying the properties of soil according to Dunlay (1975) its performance could be significantly improved.

Low-cost building materials could be produced from indigenous and inexpensive aggregate available within the vicinity of the construction site (Paramasivan & Loke, 1997). Agricultural wastes, which are abundant in this region, can also be used to supplement or replace the traditional aggregate in order to reduce cost. Coad (1995) further explained that the choice of a stabilizer is dictated primarily by economic criteria its availability and the nature of the soil.

In Nigeria today, locally sourced and developed materials show evidence of viable alternatives for effective urban regeneration and the production of decent low-cost houses according to Ajayi, (2004). In a broad sense however, the technological capacity/ capability to use local additive in improving adobe for building construction in Nigeria may be defined in two ways; firstly is the capacity to identify suitable soil and their limit states. Secondly, the capability to improve the natural characteristics weaknesses of the earth material, and standard. Such improvements for incorporation into modern housing designs and programmes, without losing their desirable natural characteristics.

In the building construction industry, quality control measures require that construction methods, materials and processes comply with laid down standard code of practice to ensure quality of the products and safety to the life-long users of the product. As Craven (2006) puts it, building codes are there as production guide. In Plateau State, traditional earth builders achieve some degree of quality improvement but mostly through trial-and-error, depending on the expertise and experience of the earth builder and the availability of the necessary additives. There is therefore every need to standardize the various aspects of the earth building practices in order to improve the quality, durability and flexibility in use, and test within the context of modern construction requirements.

History of Building Construction in Plateau State

Building is defined as a shelter in which people live, a place to live, a dwelling and to Nations, it is considered to be a critical component in social and economic fabric. Building represents one of the most basic human needs. As a unit of the environment, it has a profound influence on the health, efficiency, social behaviour, satisfaction and general welfare of the community Onibokun (1998) as cited in Kabir and Bustani

(2004). To most groups, building means shelter but to others it means more as it serves as one of the best indicators of a person's standard of living and his or her place in the society (Nubi 2008). It is a priority for the attainment of living standard and it is important to both rural and urban areas.

The history of building in Plateau State dates back from time immemorial, perhaps it began when the first man came and settled on the cold and mountainous hills of the State. According to Shehu (2002), the history of any ethnic group is as old as the group itself hence it affects all endeavours including its buildings. With this in mind, it is justified to state that the traditional buildings in Plateau State are as old as the State itself. However, there exist some variations among the buildings, though slightly different from local government to local government, from district to district and generally from locality to locality. Local conditions, for example living patterns, climate and available material resources dictate the type of houses they build. Prior to industrialization, homes were built using local materials indigenous to the area around the people. Native of the land were using wood, mud, straw, stones and grasses to construct their homes. However, it is common for almost all rural houses in Plateau State to use earth material for construction of buildings although the people had no experience of modern heating and cooling systems and so developed natural way of building in order to maximize the natural heating and cooling properties of the home.

Ezeji (1984) said that in the past, people built houses with tree branches, leaves, and even grasses. He added that recently, however, people have changed from one type of building material to another and have adapted old material in a continuing effort to obtain the best possible protection from weather and the environment.

Technically speaking, the variety of earth buildings in Plateau depends on the type of soil available, the use and the function to which the buildings are applied Norton, (1997). Over the past several decades, numerous vernacular building methods have been investigated, and in some cases reviewed and improved upon by a new-breed of Visionary Designer-Builder Kennedy, (2002).

Adobe has been in use for wall construction for a long period of time in Plateau State, traditionally dug and mix with water without due consideration to proportioning. As time pass by, the people of Plateau State became better and better at building in a quicker manner, as a result of discovery into other alternative materials and as their natural resources started to run dry, for example, wood for building homes began to be scarce as a result of farm expansion. In the early 60s, building began regularly to incorporate the kind of technology that we recognize today as being harmful to the environment. New construction opportunities presented themselves as builders explored the use of such materials as cement and steel. This offered a kind of freedom to designers' that they had never before experienced. The people of the state were no longer limited to building in a way that took the natural surrounding environment into consideration. Instead, they could create structures with any design they wanted. Owing to the increasing cost of these modern materials, the researcher is motivated by the study to find alternative materials to existing conventional ones and the need to bring down the cost of construction have compelled the desire to intensify work on cow dung and digitaria exilis with a view to investigating their usefulness wholly as a construction material.

Adobe as Material for Building Construction in Plateau State

Laterite as a major raw material for adobe (Mud) block production has been used in construction of shelter in Plateau State from time immemorial. Previous research indicates that 30% of world's present population still lives in adobe structures as asserted by (Olugbenga, Kolapo, Oludare, and Abiodun, (2007). It has been used extensively for wall construction around the world, particularly in developing countries as observed by these authors. Laterite which is the major raw materials for adobe blocks production is a cheap, environmentally friendly and abundantly available in most part of the World. Laterite has other advantages which make it potentially a very good and appropriate material for construction, especially for the construction of rural structures in the less developed countries. These advantages include: no specialized skilled labour required for the production.

Traditionally, adobe were never kiln fired hence they are referred to as unbaked adobe bricks. It consists of laterite, sometimes gravels, clay, water, and straw at un-specified proportion, mixed together by hand, formed in wooden moulds, and dried by the sun. Today some commercially available adobe-like bricks are fired. These are similar in size to unbaked bricks, but have a different texture, colour, and strength. Similarly, some adobe bricks have been stabilized containing cement, asphalt, and /or bituminous materials, but these also differ from traditional adobe in their appearance and strength. *(http:// www. old house web.com).* Today, cement is commonly used with unbaked adobe bricks, for construction in Plateau State, but cement mortars are incompatible with un-stabilized adobe blocks because the two have different thermal expansion and contraction rates. Because of this incompatibility, the strength of the adobe blocks needs to be improved in other to take cement mortars thereby avoiding the deterioration of adobe since the cement mortars are stronger than the adobe. *(**http:// www.** old house web.com).*

Manufacture of Sandcrete blocks

The blocks (all hollow) contained a mixture of sand, cement and water manufactured with the use of vibrating machine or by manual means. The blocks are used extensively in many countries of the world especially in Africa Oyekan and Kamiyo (2011). According to these authors, in many parts of Nigeria, sandcrete blocks are the major cost component of the most common buildings. However, it is pertinent to note that it is manufactured without reference to any standard specification either to suit local building requirement or for good quality work. The high and increasing cost of cement has contributed to the non-realization of adequate housing for both urban and rural dwellers. Alternatives to cement as a material for construction are very desirable in both short and long term as a stimulant for socio-economic development. Research work revealed that mix ratios of Cement to sand of 1:6 and 1:8 that is one part by volume of cement to six or eight parts by volume of coarse sand is use in the production of sandcrete blocks. In the short run, any material that can complement cement and is much cheaper will be of great interest. Over the past decade, the presence of local admixture in construction materials has been observed to impart significant improvement on their strength, durability and workability (Mental, 1994; Falade, 1990, 1997; Oyekan, 2001) cited in Oyekan and Kamiyo (2008).

Compressive Strength of Sandcrete Block

Compressive strength of brick refers to the ability of the block to withstand load or stress placed on them before they break according to King (2007). It is the maximum compressive stress that a block can withstand without being crushed. The author further emphasized that; blocks must first be tested in order to determine the strength.

The compressive strength of building units plays an important role in the durability, stability and average strength of a building. The British standard (BS 6073) blocks stipulates that the compressive strength of sandcrete blocks should be the average of 10 blocks which range between 1.8-2.5N/mm2. This implies that manufactures or users must test at least 10 blocks out of every new batch of blocks the manufactures make for the users to buy.

The compressive strength is the unit load required to cause permanent deformation. With brittle materials, such as concrete, cast iron, and ceramics, the specimens fracture along shear planes. In this case, compressive strength is the resistance to shearing stress within the specimen and, by definition, is the total load applied to the specimen divided by the cross-sectional area of the specimen.

Compressive (α) = Crushing load (N)/effective surface area (mm) in Mpa.

The compressive strength of concrete, above 5,000psi (350kgs/sq cm), is approximately 10 times as great as its tensile strength. According to British Standard (BS- 1924:1990 part 1&2) dealing with stabilized earth materials must have cured compressive strength of not less than 1.85 Mpa (mega Pascal) 268.25psi (pound per square inch). Because concrete is weaker in tension, steel reinforcing bars are used to carry the tension stresses in structural concrete (Adams 1998).

Wood is not homogeneous throughout the length or cross section of a structural member. The compressive strength of wood is much greater when the load is applied parallel to the grain than when it is applied perpendicular to the grain according to William as cited in the Encyclopaedia Americana 7(456).

Tensile strength is the unit load required to cause a material to fracture or deform permanently.

Shear Strength of Sandcrete Blocks

Shear strength is the distortion of a solid resulting from applied forces that cause plane of the solid to slide relative to each other like cards in a park. The applied forces or shearing forces, act parallel to a plane, where as tensile forces and compressive forces act perpendicular to a plane. As an example, shearing forces along two metal plates joined by rivet tend to separate the rivet into two parts, with the planes of separation parallel to the direction of the applied forces. The shearing stress set up in a solid is the applied force divided by the area of the surface over which it acts. The shearing strain, which accompanied shearing stress, is the displacement of one plane of the solid relative to parallel plane divided by the distance between the two planes (the Encyclopaedia, Americana International vol.24, 2000).

Shearing force per unit area is referred to as the shear stress, denoted by the symbol T (Greek letter tau) where **T =F/A**

Shearing strength (Mpa) of a material is the maximum stress that it can withstand in shear before failure occurs.

Water Absorption of Adobe Blocks

Water absorption of a material is the ability of that material to allow water to pass through it. It is the rate at which material absorbs water through physical or capillary action.

Absorption rate refers to the amount of water a partially immersed brick can absorb in one minute (King, 2007). Adobe blocks in its natural nature seem to have a high rate of water absorption which is not good as a construction material hence, the need for stabilisation. The effects on building is accumulation of damp in building that makes the house smell musky and can cause health problems to people especially who are asthmatic or people with other breathing problems. It can make the house feel much colder that it really is *(http: www.neverpaintagain. co.uk/article/).* Adobe building therefore deteriorates because of moisture, either excessive surface rainwater or through ground water. Successful stabilization, restoration, and the ultimate survival of an adobe building depend upon how effectively a structure sheds water. The importance in keeping an adobe building free from excessive moisture cannot be overestimated.

The erosive action of rainwater and the subsequent drying out of adobe walls and wall surfaces can cause furrows, cracks, deep fissures, and pitted surfaces to form. If left unattended, rainwater damage can eventually destroy adobe walls causing their continued deterioration and ultimate collapse. Standing rainwater that accumulates at foundation level and rain splash may cause “coving” (the hollowing–out of the wall just above ground level). Ground water (water below ground level) might be present because of a spring, a high water table, improper drainage, seasonal water fluctuations, excessive plant watering, or changes in grade on either side of the wall. Ground water rises through capillary action into the wall and causes the adobe to erode, bulge, and cove. As the water rises from the ground into the wall, the bond between the clay particles in the adobe blocks breads down. In addition, dissolved minerals or salts brought up from the soil by the water can be deposited on or near the surface of the wall as the moisture evaporates. If these deposits become heavily concentrated, they too can deteriorate the adobe fabric.

As the adobe dries out, shrinkage cracks usually appear; loose sections of adobe bricks and mud plaster may crumble. Any disturbance of the ground most especially water should, therefore be undertaken with prudence and careful planning.

Cow Dung as Additive for Improving Adobe Blocks

It is small wonder that cow dung should find itself in our modern world. Cows' and bull's dung (and Urine) in India is sacred to the Hindu religion and have many uses. Cow dung has provided man with fuel for millennia and used it as fertilizer. It may be used as a seed protector, a heat source. It is employed as a purifier, floor coating, mud brick additive, a skin tonic, mixed with crushed Neem leaves; the smoke is a mosquito repellent, dung is pond PH balancer, and it is even used to make Frisbees. Despite its technological and medicinal contribution, cow dung is not valued equally or popular everywhere. *(http://www.Herbsphere. Com/tester.htm.).*

Cow dung is commonly used in mortar for rendering wall surfaces and roof soffits. Lawson, (1999) in a study of low-cost materials for building in north-east Nigeria discovered at Kaski and Yin in the north-east arid zone, the building mortar and rendering which are much more durable are made from the same soil with cow dung added to it.

Adobe as Building material

The word "adobe" has come down over some 4000 years with astonishingly little change in either pronunciation or meaning: the word can be traced from the Middle Egyptian 2000BC meaning Mud (i.e., sun-dried) brick. As Middle Egyptian evolved into late Egyptian, Demotic, and finally Coptic 600 BC adobe was called "tobe" (Mud) brick. This in turn evolves into Arabic “at-tub” (Mud) brick which was assimilated into Old Spanish as “adobe” still with the meaning “Mud brick”. English borrowed the word from Spanish in the early 18th century.

According to Ezeji (1984) various walling materials have been used at different times in architectural history. In many parts of Africa the traditional wall consisted of kneaded mud sometimes interspersed with sticks and these can still be seen in many Nigerian towns and villages. Mud walls have the advantage of being heat resistant but are easily weakened by rain. Wall must be resistant to damp penetration. Most porous building materials swell on getting wet and shrink on drying. Mud construction is as old as man’s attempt to build home and cities, which dated back to about 10,000years. Consequently, construction in earth was developed independently in all the main cradles of civilization the banks of the Nile, the Indies and the Hwango (Houben and Guillaud, 1994). Building materials such as clay and mud require only man’s effort to make a structure from them and as a result, people in this planet live in buildings made from earth (Houben and Guillaud, 1994).

About 30 per cent of the world population (or nearly 1,500,000,000) live in home of unbaked earth, roughly 50 per cent of the population of developing countries, the majority of rural populations and at least 20 per cent of urban and semi-urban populations live in mud homes (Houben and Guillaud 1994). This assertion relate to Nigeria from the Ileabaru, or Ile Alamo of Yoruba through the Okehota form of construction in Ojirami-Ugbeke of Edo state, the duarawa finished Mud houses of Anfani Kwara State, the mud huts in Asamabari of River State, to the mud houses of the savannah region epitomized by the Friday mosque in Zaria.

There is virtually no ethnic group that does not have a traditional type earth building. Mud houses are generally constructed at a little cost or even at no cost at all, largely through self-help. Such houses are suited to the tropical and sub-tropical climatic conditions and are aesthetically pleasing and in harmony with the surroundings.

Digitaria Exilis Straw (Acha) as Additive

Digitaria Exilis Straw is a scientific name for ‘Acha’ Straw (one of the local additives to adobe), a collection of dry needle like grasses. The Acha straw is soft when dried and use as hay for feeding animals. It becomes softer and can easily be cut into small pieces at any little pressure applied. This feature makes it suitable for used as additives for improving adobe blocks. Wikipedia, (2006) defined straw, as the stalks remaining after the harvest of grains, is a renewable resource, grown annually in most farmland. It is tough and fibrous; last longer than hay, which is leafy, (US, DOE, 2004). Egypt is probably one of the first countries in the world to use straw as a building material. By 4000 B.C. Egyptian used sun dried bricks made out of clay and straw in building entire villages. Even today, clay with straw is used as building material in Egyptian rural areas (Mansour, Srebric and Burley, 2007). The Holy Book identified the used of straw mixed with earth materials for the construction of the wall of Jericho and the walls of the City of King David, by the Jews (Exodus, 1: 18).

Straw is found in abundance within the far north and the Middle Belt region of the country for feeding animals. In Plateau State in spite of its abundance, little attention is accorded to its usage in construction. It is left on the field after harvest and later burnt to ashes. Consequently, instead of burning the straw, recycling it with a mixture of adobe forms a sustainable low cost building material. This would also reduce atmospheric pollution as a result of burning. In addition to these benefits, the straw could act as a thermal insulation material for the unpleasant weather in Plateau State.

Laterite Soils and its Properties

Laterites and lateritic soils form a group comprising a wide variety of red, brown, and yellow, fine grained residual soils of light texture as well as nodular gravels and cemented soils. They vary from a loose material to a massive rock. They are characterized by the presence of iron and aluminium oxides or hydroxides, particularly those of iron, which give the colours to the soils. For engineering purposes, the term “laterite” is confined to the coarse-grained vermicular concrete material, including massive laterite. There is no consensus as to what defines a laterite, nor is there agreement as to how they are formed (Duchaufour, 1982; Jenny, 1994; Retallack, 1997). However, the U.S. Soil Survey Staff (1993) attempt to defined a laterite as a plinthite, a hematite-rich mottled red/yellow and white clay zone; others consider only the hard, hematite- and clay-rich surface crust as laterite. Relallack (1997) prefers to define a laterite as a rock or part of a soil, not a true soil.

Most laterites are encountered in an already hardened state. In some areas of the world, natural laterite deposits that have not been exposed to drying are soft with a clayed texture and mottled coloring, which may include red yellow, brown, purple, and white. When the laterite is exposed to air or dried out by lowering the ground water table, irreversible hardening often occurs, produce material suitable for use in building.

Amadi, (2010) observed that Lateritic soils are widely used as fill materials for various construction works in most part of the world. In his studies he also observed that these soils are weathered under conditions of high temperatures and humidity with well-defined alternating wet and dry seasons resulting in poor engineering properties such as high plasticity, poor workability, low strength, high water absorption, tendency to retain moisture and high natural moisture content. The effective use of these soils is therefore often hindered by difficulty in handling particularly under moist and wet conditions. Lateritic soils that present such problems during construction processes are termed problematic laterites.

The modification/stabilization of engineering properties of laterite soil is recognized by engineers as an important process of improving the performance of problematic soils and makes marginal soils perform better as a civil engineering material. According to Mansour, Srebric and Burley (2007) the application of chemicals such as ordinary Portland cement, lime, fly ash or a combination of these often results in the transformation of the soil index properties which involve the cementation of the particles. Previously, the most commonly used additive for laterite soil modification or stabilization is the ordinary Portland cement but recent studies have shown that many of the soil problems can be ameliorated by the addition of Cow dung.

History of Traditional Techniques of Adobe Construction

Adobe or sun-dried block is one of the oldest and most common building materials known to man and especially to Plateau State rural dwellers. Traditionally, adobe blocks were never kiln fired. Unbaked traditional adobe blocks consisted of laterite, sometimes gravel, clay, water and often non-proportioned quantity of grasses mixed by matching severally with legs and frequent turning with shovel until it attends its plastic consistency. Sometimes left overnight to attend its workability before using it the next day.

Traditionally, no mechanical mixers were used. The mixing was done by traditional methods with human power. They worked the mud and straw with shovels and then stomped on the mixture (like smashing grapes for wine) until it reached the desired consistency. The mixing stage was generally done in the evenings and the mixture was left to dry into an optimum, dough-like consistency until the next working day. In some cases, improper mixing affected the quality of the mud bricks. For example inadequate mixing causes some section of the mixing to have concentrations of straw, which decreased the strength of the bricks.

The prepared adobe is then placed in wooden forms mould tamped and level with hand. The blocks are then "turned – out" of the mould and left to dry in an open space under the dry sun for a non-specified curing periods. The adobe blocks produced under this condition shrunk and swollen constantly with their changing water content. Their strength also fluctuates with their water content; the higher the water content, the lower the strength. According to Lal (1995) these problems associated with adobe can be overcome by suitable improvements in design technology, such as improving soil characteristics or properties and improvements in structural techniques. This assertion is therefore in agreement with this study which is aimed at adopting new techniques for improving adobe block for construction of buildings in Plateau State.

The traditional method of wall construction with adobe includes the following:

i. Mud lump construction: According to Mathur (1987), this is the simplest method, of local soil, which is not too clayed or too sandy, is first dug out and then mixed with requisite amount of water to form lumps of good consistency. Lumps are manually placed in layers. While laying the lumps, care is taken to see that no space is left in the body of the wall. Each layer is placed on alternate days to make allowance for sufficient dry time. Such houses are cheaply built through self-help though they are not very durable.

ii. Sun-dried adobe wall construction: this type of construction used sun-dried blocks prepared from local soil. Water is added to the soil in the requisite quality. The prepared mud is then moulded into the shape of blocks of suitable size using wooden mould. Sun-dried mud blocks are laid in courses in mud mortar. The joints are staggered in each course (Mathur, 1987). The wall is raised in stages, about 1m high everyday up to a height of 3m to provide clear headroom. It is finally rendered.

iii. Rammed earth construction; in this method, of adobe construction, damp or moist earth is rammed between temporary, movable timber frameworks. The soil to be used for such construction should be free from deleterious contents such as organic matters of vegetable origin. Mathur (1987) maintained that the preferred soil for such construction is “sandy loam”. This soil prepared for ramming is just moist enough to form a compact well when pressed between cupped hands.

Shehu (2002) observed that another traditional way of constructing adobe building was to place layers of soil on top of each other usually by letting one layer dry out before the next one is added.

Socio-economic and Environmental Reasons for Alternative Materials

Cost of building materials has made construction and development of housing very expensive, and as such the low and middle income groups in Nigeria cannot afford to build or own a house. According to Nwachukwu and Asaoh, (1989) cost reduction has remained elusive in construction industry because of strong attachment to conventional building materials.

Today in most part of the world, improvement in earth building technology has made it begin to gain technical and social acceptance among the rich and the poor (Maini, 2002). Those who recognized the environmental social and economic cost of current ways of construction believed that earth building provides part of solution to the complex world wide problem of sustainable living (Kennedy, 2002). Apart from the issue of reducing unemployment and creating micro industries, the direct cost saving in construction is between 8 and 18per cent (Burrough, 2002a and Howe, 1992). Earth building is in every aspect collaborative and as such can form the hub of other self-help initiatives within communities providing both capital and methodology (Ifeka, 2004).

According to Robson in Burrough, (2002b) earth houses are economical to build and no other building material can match the relationship of earth building to the environment. Experience has shown that earth remains a viable material, owing to the costly increases in production of modern building materials. Aggarwal (1981), Doat, Hays,Houben, Matuk and Vitoux (1991) stated that the appropriate use of earth construction produces cost effective and comfortable buildings.

Literature on the economic benefits of contemporary stabilized earth construction with additives like cow dung and digiteria exilis is scanty and very few structured research is available. Although Soil has been, and continue to be the most widely used building material throughout most developing countries. It is cheap, available in abundance and simple to form into elements (Adam and Agib, 2001; Morris and Booysen, 2000).

Review of Related Empirical Studies

Several studies have been carried out all over the world on earth building and techniques. Some have been specific on soil stabilization for earth building. Empirical studies revealed that earth remains a viable material, given costly increases in energy consumption caused by the production of modern building materials (Agarwal, (1981) and Mongomery (2002) cited in Hadjri, Osmani, Baiche, and Chifunda, (2007). Agarwal (1981) and Doat et al (1991) stated that the appropriate use of earth construction produces cost-effective and comfortable buildings.

Amadi, (2010) observed that Lateritic soils are widely used as fill materials for various construction works in most part of the world. In his studies he also observed that these soils are weathered under conditions of high temperatures and humidity with well-defined alternating wet and dry seasons resulting in poor engineering properties such as high plasticity, poor workability, low strength, high water absorption, tendency to retain moisture and high natural moisture content.

Compressed stabilised earth blocks (CSEBs) were successfully used for low-income housing in Sudan (Adam and Agib, 2001 cited in Hadjri, Osmani, Baiche, and Chifunda, (2007). According to Hadjri, et al (2007) in Zambia, housing construction using conventional materials (brick concrete) is too expensive for the majority in urban areas, where transport amounts to approximately 40 per cent of the total material cost. In a research carried out by Hadjri et al (2007), 10 residents living in Zambian rural earth- constructed houses were interviewed on five key issues: durability, affordability, living conditions, aesthetics and their general preference with regard to living in an earth dwelling rather than a 'modern' house. The study revealed that all interviewees agreed that earth dwellings were very affordable in comparison with houses built with conventional materials (brick, concrete). Thus, contemporary earth construction is economically beneficial in the construction of low-cost urban building. Howe (1992) in an earlier study, concluded among other things, that earth can be used in a number of ways to construct dwellings and that by making several important changes to the traditional manufacture of mud-blocks and to their incorporation into modern buildings, their performance can be enormously improved, while keeping their desirable characteristics. Based on the findings from his study, Howe cautioned that discarding such a plentiful resource as earth was never a good idea and people are beginning to see it. Ifeka (2004) in a Ford Foundation Sponsored work on "Nigeria Building Better Lives Brick-by-Brick", discovered that earth is the most immediate and locally available material that provides the cheapest and lowest impact on construction material; that in many areas the earth material can be extracted from the building site itself and that earth building tend to be more comfortable and energy efficient that many other contemporary houses made of other materials.

In the African context, Ngowi (1997) researched and published a significant amount of literature on the potential of earth construction to address the urban housing crisis without emphasising the cost-benefit analysis. Morris and Booysen, (2005) examined the technical aspects of CEB as a building material in Southen Africa. Sanya (2007) researched the sustainability of earth Architecture in Uganda. His research proved that CSEB is not economically beneficial in the Ugandan context because of the unavailability of cement. Longfoot's (2006) research aimed at developing a low-cost adobe block using locally available sand in Botswana. Stulz and Murkerji (1993) proved that earth is one of the most appropriate building materials for urban dwellings. A Nigerian author, Ogunsusi (1994-1996), cited in Sanya (2007), has written five books with recommendations for host practices in CEB construction that have shown that earth construction is economically beneficial to urban housing.

The study of an improvement of adobe housing by Pa'al and Knut (1981) revealed that it is a common problem for all rural houses in tropical developing countries for adobe or mud to be used in one way or another. More recently, burnt bricks and solid cement has been introduced. They stresses that quality of block produce varies from very good to poor. Dimensions of such blocks are inaccurate and surfaces are rough, but they will still represent a huge improvement on the traditional materials. More so, if firewood is available, the self help builder only needs to invest his own labour to produce a building material which can be used for foundations, walls, floors and even in some cases roofing.

Studies on the use of lime as a stabilizer to improve performance of adobe conducted by Coal (1979) on two different adobe samples revealed that adobe is the cheapest and probably the oldest building material known to Mankind. Because of its cheapness abundance and accessibility, it is still commonly used in tropical developing countries, particularly for houses by self-help method. In a similar research undertaken in Pakistan by Jamal and Sheikh (1987) to improve the strength and characteristics of adobe stabilized with cement to withstand normal flood water in rural areas, revealed that soil including adobe, should be free from rubbish, vegetable matter and salts.

Some of the pioneering studies on soil stabilization in Nigeria include that of Chukwudebe (1976) where cement was used to stabilize laterite for block moulding. In 1977, Agarwal did another study in which groundnut husk-ash (GHA) mixed with cement and soil was used to produce panels of 300x300x25 sizes. Osayere (1984) and Oraedu (1985) studied the effects of modifying concrete and stabilizing earth blocks with Rice-Husk-Ash (RHA) respectively, and discovered that chemical composition of rice-husk-ash was comparable to that of Portland cement and completely different from that of un-burnt rice- husk.

Currently, the government of Nigeria has a policy that encourages research and development into indigenous technology of building material and utilization under her National Economic Empowerment and Development Strategy (NEEDs). So far, research efforts at the Nigeria Building and Roads Research Institute (NBRRI) in Ebonyi State are skewed in favour of design and production of tools and equipment for the extraction/production of local building materials (Isoung, 2004).

Summary of Review of Related Literature

From this chapter, it is obvious that because of high demand for housing and with consequence high cost of conventional walling materials which are beyond the reach of low-income earner, it is important to explore other alternative local building materials. Locally sourced materials show evidence of replacing the foreign materials if properly harnessed. Because of its environmental friendly, its production does not require complex skills and it is economical to produce.

Laterite, being the major raw materials for such local construction is abundant in every community in Plateau State. Obtained in its natural form as noted in this chapter is not stable for construction purpose, hence the need to improve its properties with local additives to make it suitable for construction. Certain additives have been found to be suitable for modifying the properties of soils for construction such as asphalt emulsion, gypsum, Rice Husk, Sawdust, Cement, animal blood and Urine. Although literature on Cow Dung and Digitaria exilis straw is scanty, because of its plastic nature they have evidence of improving the strength of adobe for construction.

The absence of appropriate technique and knowledge of using these additives by the traditional adobe builders in Plateau State is what is lacking and this have led to so many construction defects such as; collapse of structures, regular maintenance of walls and high water absorption among others.

Despite their advantages, adobe structures have some shortcomings. Adobe is brittle and it has a low compressive, tensile and shears strength. Up to now great losses have occurred due to collapse of adobe structures. A huge number of people living in adobe structures have lost their lives and there has been great damage to these buildings. Besides, low water resistance is its weakest feature. The gap this research intends to fill therefore is to address these shortcomings of adobe structures by exploring alternative techniques of determining appropriate standard mix proportion that would increase the compressive, tensile, shear strength and water resistance rate of the adobe blocks. In particular the researcher hopes to achieve this by using digitaria exilis straw and Cow dung as additives to adobe. The objective of mixing additives with adobe is therefore to improve its volume stability, strength and properties like permeability and durability. Although efforts have been made to improve the adobe to ensure its wider acceptance, no literature is available on the use of cow dung and Digitaria Exilis straw as additives to improve adobe for construction.

Research into earth building materials appears to contain more of an academic pursuit waiting to be harnessed and translated into concrete technological improvement for earth building practice in Nigeria. In spite of the numerous studies on how to improves earth materials for construction, not much literatures was fund on the use of Cow dung and Digitaria Exilis as additives for improving the characteristics of soil materials for construction of buildings. This is the gab this study aimed to bridge.

CHAPTER III

METHODOLOGY

This chapter described the methods, procedures and materials used in carrying out the research. The research design, area of the study, instrument for sample collection, methods of sample collection, sample preparation, specimen production, curing of specimen, method of data collection and method of data analysis were also described.

Design of the Study

The research design employed in this study was Research and Development (R & D). Research and Development design according to Nworgu (2006) is aimed at developing and testing the suitability of a product and field-test to ensure its effectiveness. Janet (2001) affirmed that this research method is aimed at producing materials used in schools; such materials include learning materials which include teaching aids to facilitate pupils' learning as well as teacher training programmes. He further maintained that a lot of money and time is needed to develop and produce objects. Such objects are tested and even revised until the required specific is met. The design was found appropriate for the study since the study focused on developing and improving the performance of adobe block produced from two different local additives to improve the properties of buildings constructed with adobe.

Area of the Study

The area of the study was Plateau State and the study concentrated on eight local government areas which were Pankshin, Mangu, Bokkos Riyom Barkin Ladi, Jos-South, Bassa and Jos North Local Government Area(s). The buildings constructed with adobe in these areas are easily washed away by water which makes it difficult to be used for construction. It was also noticeable that in these areas, an adobe short coming makes it easy for rodents to dig holes into the walls.

Instruments for Sample Collection

Instruments used for the collection of the sample were; shovel, wheel barrow, empty bag of cement, sack Head Pan and Pick Axe. The wheel barrow was used to transport the cow dung to the mixing area. The Head Pan was used for conveying already mixed specimen for moulding. Sacks was used for conveying laterite from various areas of study to the production area and digitaria exilis straw from the field after cutting with cutlass to an approximate sizes ranging between 50mm-75mm. Pick Axe was used for digging the soil to convenient depth where the appropriate soil sample was found.

The adobe that was used for this study is reddish-brown adobe (laterite) taken from a depth of not less than 0.6m below ground level using a Pick Axe. This was to ensure complete absence of top soil. The cow dung was collected at Kara in Jos South Local Government while Digitaria Exilis Straw (Acha) was collected at the open field in Heipang, Barkin Ladi Local Government.

The following equipment were used in carrying out the experiment, sieve of size 0.850mm, wooden mould with internal dimension of 290mm long, 140mm thick and 100mm high was considered to be an acceptable size, gravimetric scale, long meter rule, shower tap, compaction machines, triaxial machine and permeability machine.

Preparation of Sample

The materials for this study were weigh batched because weigh batching is reliable, uniform and consistent quantity could be maintained. Weigh batching gives much more accurate results Seely (1995). According to Shetty (2001) weigh batching is the correct method of measuring the material. The author maintained that use of weigh system in batching, facilitates accuracy, flexibility and simplicity. The cow dung was gauged by weight by filling it in an empty sack of cement which is equal to 50.0 kg. The used of empty sack was pertinent so as to maintain uniformity in the measurement. The soil samples after sieving with sieve No 2o (0.850mm) was batched first, followed by additives at various mix proportion added to soil samples. The materials were mixed thoroughly while still dry by turning with shovel until the homogenous mixture was obtained.

Specimen Production

Water was added to the dry mix and mixed thoroughly to a uniform consistency for workability. Each of the specimen groups based on the soil type and area where it was collected was worked-on, on separate days to avoid complication in the specimen identification. The mixture was poured into the lubricated wooden mould and was compacted manually using a wooden tamping rod. A total of 280 samples of blocks were produced for the experiment. Five samples each were tested using three trial proportions for the different soil samples collected from the eight Local Governments' Areas to determine their compressive, shear, tensile and water absorption.

Curing of the Specimens

The blocks were air dried for 28 days in the open field because at 28 days the adobe blocks would have been practically suitable for handling and safe for use in building construction. During the curing period of (28 days), the blocks were covered with grasses to avoid spontaneous drying that would cause shrinkage and leads to cracks. Laboratory test commences after 28 days of curing the specimen in an open field. The 28 days curing period was to allow for complete drying of the blocks.

Method of Data Collection

Data was collected based on laboratory experimental research principles by observation and recording values. Specimens were tested at different times and for different proportion of the additives for compressive, tensile, shear strength and water absorption. Readings for each specimen was recorded until the entire specimens subjected to 28 days curing period were tested.

Methods of Data Analysis

The conventional adobe blocks used for building construction in these Local Government areas were tested first and the compressive, tensile and shear strength and also water absorption rate recorded. Subsequently, the adobe blocks with the additives were also tested of the same properties to see whether there was any change in the strength and water absorption.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

In this chapter the data gathered from the various laboratory tests conducted are presented. The presentation of these results follows the order of the research questions been formulated.

Tests Results

The summary of the results obtained from the various laboratory experimental tests conducted on the adobe blocks to determine their suitability as wall construction material and for other construction purposes is presented in tables 1 - 6. The specimens were tested after 28 days of curing.

The various tests carried out included compressive strength, water absorption, shear strength and tensile strength for blocks produced using cow dung and digitaria exilis as stabilizers at a mix proportion of 1:4 and 1:3 for each additive. The tests were conducted in compliance with the specification of British Standard (BS-1924:1990) parts 1&2 which deals with stabilized earth materials.

The results of the tests are presented in Table 1

Results of Laboratory Test of Adobe Blocks Produced by Conventional Methods

Areaof Study	Load Reading KN	Weight of cubes	Compressive Strength N/mm^2	Shear Strength Mpa	Tensile Strength Mpa	Water Absorption %	Curing period
Pankshin	30	2071	1.45	1.02	0.004	9.91	Not Applicable
Mangu	20	1820	1.11	1.01	0.002	18.13	
B/Ladi	25	2015	1.24	1.01	0.002	11.66	
Riyom	30	2071	1.45	1.02	0.004	9.91	
Jos South	30	2071	1.45	1.02	0.004	9.91	
Jos East	35	2280	1.54	1.05	0.043	26.54	
Jos North	30	2071	1.45	1.02	0.004	9.91	
Bassa	30	2071	1.45	1.02	0.004	9.91	

Table 1 presents the results of adobe blocks produced by using the conventional method. The results showed low compressive strength, low shear strength, low tensile strength of the blocks. It could also be observed that the sample of adobe blocks produced with laterite from Pankshin Local Governemt Areas have $1.45N/mm^2$, $1.02N/mm^2$, 0.004Mpa and 9.91% as compressive, shear and tensile strength and water absorption respectively. The results showed a little decrease in strength for Mangu Local Government Area but increased water resistance of 18.13%. Results of sample of adobe blocks for Barkin Ladi presents 1.24N/mm2, 1.01Mpa, 0.002Mpa and 11.66% for compressive, shear, tensile strengths and water resistance respectively. However, the results obtained from samples of adobe blocks produced from Riyom, Jos-south, Jos-North and Bassa Local Government Areas were found to be relatively the same owing to the nature of soil particles which containts a little percentage of silk that aids in binding the soil particles closely together during compaction. For all the samples produced from this conventional method, the curing period was ignored.

Research Question 1

What are the mix ratios of cow dung to adobe and digitaria exilis to adobe will block give optimal compressive, shear, tensile strengths and water resistance for building purpose?

Data for providing answer to research question 1 are presented in Table 2&3.

Table 2
Compressive, Shear, Tensile Strengths and Water Resistance of Adobe Blocks with Mix Ratio of 1:4 Adobe (Cow Dung)

Study Area (LGAs)	Compressive Strength (N/mm^2	Shear Strenght (Mpa)	Tensile Strenght (N/mm2	Water Absorption %
Pankshin	2.01	1.97	0.05	7.80
Mangu	2.01	1.00	0.03	8.42
Bokkos	2.02	1.23	0.02	8.95
Riyom	2.01	1.10	0.02	9.03
B/Ladi	2.02	1.12	0.06	10.81
J/South	2.04	1.20	0.04	8.50
Bassa	2.03	1.05	0.03	9.08
J/North	2.00	1.30	0.04	7.12
Average	**2.02**	**1.25**	**0.036**	**8.71**

Table 2 above presents the summary of the Laboratory test results, of compressive strength test, tensile strength test, shear strength test and water resistance tests of adobe blocks at the mix proportion of 1: 4 for cow dung to adobe. The results indicated that the compressive strengths for all the samples of adobe blocks produced from this mix ratios were between 2.01N/mm^2 and 2.04N/mm^2. Maintaining ratio 1:4 for Cow dung to adobe, the samples were found to have average shear strength of 1.25Mpa of sample produced from all the Local Government Areas studied. Similarly, the Tensile strength which range between 0.02Mpa and 0.06Mpa was obtained with average tensile of strength of 0.0036Mpa. The average percentage of water absorption at ratio of 1:4 of cow dung to adobe was found to be between 7.12% and 10.81% with the average water absorption of 8.97%.

Table 3

Compressive, Shear, Tensile Strengths and Water Resistance of Adobe Blocks with Mix Ratio of 1:3 Adobe (Digitaria Exilis)

Study Area (LGAs)	Compressive Strength (N/mm2	Shear Strenght (Mpa)	Tensile Strenght (N/mm2	Water Absorption %
Pankshin	2.00	1.45	0.003	8.02
Mangu	2.02	1.02	0.02	7.05
Bokkos	2.09	1.99	0.03	8.40
Riyom	2.05	1.00	0.01	7.00
B/Ladi	2.01	1.05	0.04	9.33
J/South	2.03	1.07	0.02	8.01
Bassa	2.06	1.22	0.01	9.00
J/North	2.04	1.08	0.05	6.99
Average	**2.04**	**1.44**	**0.080**	**7.98**

Table 3 above presents the summary of the Laboratory test results, of compressive strength test, tensile strength test, shear strength test and water resistance tests of adobe blocks at the mix proportion of 1:3 for digitaria exilis to adobe. It was observed that the ratio 1:3 of digitaria exilis to adobe gave the compressive strengths which range between 2.01N/mm^2 and 2.09N/mm^2 the average compressive strength at these ratios was found to be 2.04N/mm^2. The samples were found to have shear strengths which range between 1.00Mpa and 1.99Mpa and with average of shear strengths of 1.44Mpa for all the samples produced from the Local Government Areas. Similarly, the Tensile strengths which range between 0.01N/mm^2 and 0.05N/mm^2 were obtained with average tensile strength of 0.080 N/mm^2. The results also indicated that the ratio of 1: 3 of digitaria exilis to adobe for all the Local Government showed water absorption percentage of between 6.99% and 9.33% and average water absorption of 7.98%.

Research Question 2

What are the compressive strengths of adobe block mixed with cow dung and adobe blocks mixed with digitaria exilis straw (Acha)?

Data for answering research question 2 are presented in Table 4

Table 4
Compressive Strength of Adobe Block Mixed with Cow Dung and Adobe Blocks Mixed with Digitaria Exilis Straw (Acha)

Study Area LGAs	Compressive strength of Digitaria Adobe Blocks at 1:4 and 1:3		Compressive strength of Cow Dung Adobe blocks at 1:4 and 1:3	
Pankshin	2.00	2.00	2.01	1.70
Mangu	2.03	2.02	2.01	1.79
Bokkos	2.01	2.09	2.02	1.60
Riyom	2.02	2.05	2.01	1.75
B/Ladi	2.20	2.01	2.02	1.80
J/South	2.04	2.03	2.04	1.75
Bassa	2.05	2.06	2.03	1.95
J/North	2.03	2.04	2.00	1.75
Average	**2.05N/mm^2**	**2.04N/mm^2**	**2.02N/mm^2**	**1.76N/mm^2**

The results shown indicated the results of compressive strength obtained from the sample produced from the mixture of cow dung to adobe and digitaria exilis straw (Acha) to adobe. Two ratios were adopted for each of the sample collected from each study area. For Pankshin Local Government Area the sample gave the compressive strength of 2.00N/mm^2 for ratio 1:4 and 2.00N/mm^2 at ratio 1:3 of adobe blocks made from digitaria exilis. Similarly, compressive strength of between 2.00N/mm^2 and 2.04N/mm^2 at ratio 1:4 for cow dung to adobe and 1.60N/mm^2 and 1.95N/mm^2 for digitaria exilis to adobe was obtained for all the block samples from the study areas. The results presented gave the average compressive strengths of 2.05N/mm^2 and 2.04N/mm^2 for ratios of cow dung to adobe at 1:4 and 1:3. The same ratios gave compressive strengths of 2.02N/mm^2 and 1.76N/mm^2 for digitaria exilis to adobe.

Research Question 3

What is the tensile strength of adobe block mixed with cow dung and adobe blocks mixed with digitaria exilis straw (Acha)?

Data for answering research question 3 are presented in Table 5

Table 5
Tensile Strength of Adobe Block Mixed with Cow Dung and Adobe Block Mixed with Digitaria Exilis Straw (Acha)

Study Area LGAs	Tensile strength of Cow Dung Adobe Blocks at 1:4 and 1:3		Tensile strength of Digitaria Exilis Adobe blocks at 1:4 and 1:3	
Pankshin	0.05	0.04	0.35	0.003
Mangu	0.03	0.02	0.50	0.02
Bokkos	0.02	0.05	0.40	0.03
Riyom	0.02	0.02	0.15	0.01
B/Ladi	0.06	0.05	0.25	0.04
J/South	0.04	0.03	0.25	0.02
Bassa	0.03	0.02	0.24	0.01
J/North	0.04	0.03	0.40	0.05
Average	**0.036**	**0.033N/mm^2**	**0.32N/mm^2**	**0.080**

The results in the table showed the tensile strength of adobe blocks mixed with cow dung and adobe blocks mixed with digitaria exilis produced from the mixed proportions of 1:4 and 1:3 for cow dung to adobe and same ratios for digitaria exilis to adobe. The results revealed that tensile strength for Cow dung to adobe is between 0.02Mpa and 0.06Mpa and 0.02Mpa-0.05Mpa. The results obtained for the ratio1:4 of digitaria exilis to adobe is between 0.15Mpa and 0.50Mpa, and 1:3 gave between 0.01Mpa and 0.05Mpa. The average tensile strength of 0.036Mpa and 0.033Mpa was obtained for mixture of Cow dung to adobe at ratios 1:4 and 1:3. For digitaria exilis straw to adobe at ratios 1:4 and 1:3 the average of 0.32Mpa and 0.080Mpa was found.

Research Question 4

What is the shear strength of adobe block mixed with cow dung and adobe block mixed with digitaria exilis straw (Acha)

Data for answering research question 4 are presented in Table 6.

Table 6
Shear Strength of Adobe Blocks Mixed with Cow Dung to Adobe and Digitaria Exilis to Adobe

Study Area LGAs	Shear strength Cow Dung Adobe Blocks at 1:4 and 1:3		Shear strength of Digitaria Exilis Adobe blocks at 1:4 and 1:3	
Pankshin	1.97	1.22	2.70	1.45
Mangu	1.00	1.45	2.45	1.02
Bokkos	1.23	1.35	2.34	1.99
Riyom	1.10	1.30	2.10	1.00
B/Ladi	1.12	1.58	2.00	1.05
J/South	1.20	1.00	1.96	1.07
Bassa	1.05	1.20	2.05	1.22
J/North	1.30	1.45	1.77	1.08
Average	**1.25Mpa**	**1.32Mpa**	**1.77Mpa**	**1.44Mpa**

The shear strength of the adobe block sample stabilized with Cow dung at ratios of 1:4 and 1:3 and with digitaria exilis using the same ratios is presented in table 5. The results showed the shear strength of between 1.00Mpa and 1.97Mpa, and 1.00Mpa and 1.58Mpa for sample at ratio of 1:4 and 1:3 respectively for Cow dung to adobe. In addition, the shear strength of between 1.77Mpa and 2.70Mpa, and 1.00Mpa and 1.99Mpa for sample stabilized with digitaria exilis straw to adobe at ratios 1:4 and 1:3 respectively was obtained. The results also showed the average of 1.25Mpa and 1.32Mpa shear strengths for ratios of 1:4 and 1:3 for Cow dung to adobe and average of 1.77Mpa and 1.44Mpa for digitaria exilis to adobe at ratios of 1:4 and 1:3.

Research Question 5

What is the water absorption rate of adobe block mixed with cow dung and adobe block mixed with digitaria exilis straw (Acha)

Data for answering research question 5 are presented in Table 7

Table 7
Water Absorption Rate of Adobe Blocks Mixed with Cow Dung and Adobe Blocks Mixed with Digitaria Exilis

Study Area LGAs	Water Absorption of Cow Dung Adobe Blocks at 1:4 and 1:3		Water Absorption of Digitaria Exilis Adobe blocks at 1:4 and 1:3	
Pankshin	7.80	21.80	21.95	8.02
Mangu	8.42	21.70	21.87	7.05
Bokkos	8.95	21.75	21.70	8.40
Riyom	9.03	21.85	21.90	7.00
B/Ladi	10.81	21.70	21.80	9.33
J/South	8.50	21.60	21.85	8.01
Bassa	9.08	21.80	21.75	9.00
J/North	7.12	21.75	21.90	6.99
Average	**8.71%**	**21.75%**	**19.46%**	**7.98%**

Table 6 presents the results of percentage of water absorption of adobe blocks after immersion in water for 7hours. The adobe blocks were produced by stabilizing with Cow dung at ratios of 1:4 and 1:3 and same ratios for digitaria exilis straw. It could be observed from the table that the percentage of water absorbed by the sample produced after stabilizing with cow dung is between 7.12% and 10.81%, and 21.60% and 21.85% at ratio 1:4 and 1:3 respectively and for sample stabilized with digitaria exilis the percentage of between 21.70% and 21.95%, and 6.99 and 9.33% was obtained. The results showed the average percentages of water absorbed at ratio of Cow dung to adobe as 8.71% and 21.75%. Ratios of digitaria exilis to adobe have average of 19.46% and 7.98%.

Findings

The following findings were made from the study;

A. Adobe blocks produced by conventional methods

1. The nature of soil from the various study area has great influence on the durability of adobe blocks.
2. Adobe blocks produced with laterite from Mangu, Barkin Ladi and Jos East Local Government Areas have higher water absorbtion rate.

B. Compressive, shear, tensile and water resistance of adobe blocks with mix ratio of 1:3 of adobe to digitaria exilis.

1. The specimen gave the average compressive strength of 2.05N/mm^2 and 2.04N/mm^2 for adobe blocks stabilized with cow dung and digitaria exilis at ratio 1:4 and 1:3 respectively.
2. The average shear strength of 1.25 Mpa and 1.32Mpa was obtained for cow dung to adobe at ratio 1:4 and 1:3, 1.77Mpa and 1.44Mpa for digitaria exilis to adobe at the same ratio.
3. Blocks stabilized with Cow dung and digitaria exilis straw (Acha) at ratio 1:3 and 1:4 respectively gave average tensile strength of 0.036N/mm^2 and 0.033N/mm^2 at ratios of 1:4 and 1:3 of cow dung to adobe and tensile strengths of 0.32N/mm^2 and 0.080N/mm^2 for the same ratio adopted for digitaria exils straw to adobe.

4. The ratios of 1:4 and 1:3 gave the average percentage of water absorbed after immersion in water for 7hours as 8.71% and 21.75% for cow dung to adobe, 19.46% and7.98% for same ratios of digitaria exilis to adobe.

C. Compressive strength of cow dung and adobe blocks mixed with digitaria exilis straw (Acha)

1. For ratio of digitaria exilis to adobe at mixed ratio of 1:4 and 1:3 the average compressive strength of 2.02N/mm^2 1.76 N/mm^2 was obtained.

2. For cow dung to adobe at 1: 4 and 1:3 the findings revealed the compressive strength of 2.05N/mm^2 and 2.04N/mm^2.

D. Tensile strength of Adobe blocks mixed with cow dung and adobe blocks mixed with digitaria exilis straw (Acha)

1. Tensile strength of Cow dung to adobe at ratios 1:3 and 1:4 as 0.036N/mm^2 and 0.033N/mm^2 respectively.

2. Adopting the same ratios for Digitaria Exilis straw (Acha), 0.32N/mm^2 and 0.080N/mm^2 average tensile strength was obtained.

E. Shear strength of adobe blocks mixed with cow dung and adobe blocks mixed with digitaria Exilis straw (Acha).

1. The adobe blocks produced from the mix proportions of Cow dung to adobe at 1:4 and 1:3 gave the average shear strength of

1.25Mpa and 1.32Mpa, respectively. The same ratios was adopted for adobe blocks stabilized with digitaria exilis straw (Acha) and shear strength of 1.77Mpa and 1.44Mpa was obtained.

F. Water Absorption rate of Adobe Blocks stabilized with Cow dung and digitaria exilis.

1. The result revealed that ratio 1:4 and 1:3 of digitaria exilis (Acha) adobe gave average 8.71% and 21.75% percentage of water absorbed.
2. The same ratios adopted for Cow dung to adobe gave average percentage of water absorbed as 19.46% and 7.98%.

The following were the major findings of the study:

1. The nature of the digitaria exilis straw (Acha) distinguishes itself from other organic materials hence makes the straw a good earth material stabilizer.
2. It was found that cutting the digitaria exilis straw into uniform sizes has great influence on the durability of the blocks as it was well spread during mixture.
3. The combined interaction effects of differences in the stabilizer type, changes in the soil type and variation in the mix proportion significantly affects the compressive, shear, tensile strengths and water absorption rate of the adobe blocks hence the variation in the results obtained.

4. The mixture of cow dung to adobe produced more plastic and workable adobe than the mixture of digitaria exilis straw (Acha) to adobe.

Discussion of the Findings

Table 1 above showed laboratory results of adobe blocks produced by adopting the conventional methods of production. The specimens were produced without any stabilizing agent and also from addition of straw without any predetermined proportion as has been practiced. The curing period was not determined. The result of the tests revealed that the specimen had low compressive, shear and tensile strength. The percentage of water absorption was also found to be higher than the specimen under study. This significant change however, may be attributed to the parameters under which the present study was carried out which is in length with the assertion of North, 1997 & Kerali, 2001 which states that for soil to satisfy the required qualities as construction material, it needs to be improved because the soil (earth) material as found in its natural state is not durable.

The results shown in Tables 2,3,4 and 6 above revealed that adobe stabilized with digitaria exilis straw and cow dung at mix proportions of 1:4 and 1:3 respectively produced the best result with high compressive strength.

The result in Table 4 revealed that after several trial proportioning of the stabilizers with adobe to determine the optimal compressive strength of adobe blocks, it was discovered that ratios 1:3 and 1:4 of cow dung to adobe has the compressive strength of 2.04N/mm^2 and 2.05N/mm$_2$ and digitaria exilis to adobe with the same ratio gave compressive strengths of 2.02N/mm^2 and 1.76N/mm^2 respectively. the compressive strength of adobe block obtained by stabilizing with cow dung at ratio 1:3, 1:4 and with digitaria exilis straw at ratio 1:4 fall within the acceptable standard for earth blocks according to the British Standard (BS-1924-1990 part 1&2) which gives the acceptable compressive strengths range of between 1.8 and 2.5N/mm^2 and it also complied with Dunlay (1975) which says the performance of soil (earth) could significantly improved by modifying its properties with stabilizers.

Tables 5 and 6 showed the summary of results for shear and tensile strength. The results revealed that the blocks made from these additives have poor shear and tensile strength. This revelation is in compliant with Adams (1998) where it is stated that building materials like stone, brick and concrete are poor in tension and are not normally used where tensile stress will occur- unless they are reinforced with another material like steel which can provide strength in tension. Perhaps the reason for the low tensile strengths as observed in the table. However, the blocks produced with these additives can be recommended for use as non-load bearing walls.

Using the same design, as shown in Table 7 it could be observed that the product has the lowest rate of water absorption, as only between 7.98% to 8.71% quantity of water was absorbed after immersion in water for as long as 7hours. This result indicated that the adobe blocks produced with these stabilizers could be used for partitioning and for non-load bearing walls this result complied with the study of (King, 2007) which revealed that adobe in its natural nature seem to have a high rate of water absorption which not good as a construction material hence the need for stabilization.

CHAPTER V

SUMMARRY, CONCLUSION AND RECOMMENDATIONS

This chapter presents the summary of the study as well as conclusion drawn from the findings of the study. Recommendations are then presented based on the findings of the study, while implications of the study from the laboratory results obtained are stated.

Re-statement of Problem

The quest for the use of alternative building materials in Nigeria is pertinent owing to the high cost of modern materials. This situation prompted the use of other alternative building materials like Bamboos, Stones, Clay products, and Wood which are dependable and not quite expensive to acquire. Adobe materials could be found in abundance in Plateau State and have been in use as walling materials from time immemorial. Consequent to the traditional method been adopted for construction, adobe is prone to water erosion and attack by termites, it does not withstand weather effects, often, rainstorms caused a lot of damage to the adobe walls thereby requiring regular maintenance which consumed time and labour. The use of this conventional method of adobe blocks production have the problems of causing cracks due to drying shrinkage, high rate of water absorption which leads to many houses collapsing during heavy rain fall, rodents boring holes easily in the walls. The blocks produced using this method have low compressive strength, low shear strength, low tensile strength and high water absorption which makes it not desired as walling materials. Owing to this devastating effects caused by the adoption of the traditional method and with increased demand for housing, the traditional building system has not satisfied the need for adequate building material and techniques for construction in Plateau State. Hence, the challenge for this study to determined the technique to improve adobe blocks used for building construction.

Summary of Procedures Used

The major raw material used in this study was reddish brown laterite obtained from various spots within the study areas. The laterite was sieved to extract vegetable matters. The two major variables used for stabilization were Cow dung and Digitaria exilis straw (Acha). The cow dung was grounded to powder like substance and the digitaria exilis straw cut into sizes. The cow dung and digitaria exilis straw were later mixed separately with the laterite to a homogenous colour after which quantity of water was added and subsequently mixed to a plastic stage. The mixed adobe was poured in a wooden mould lubricated with oil to avoid sticking to the sides during production. The fresh adobe blocks were cured for 28 days in an open space. The samples were then taken to the soil laboratory of the Civil Engineering Department of Plateau State Polytechnic, Barkin

Ladi to determine its compressive, shear, tensile strengths and for water resistance.

Implications of the Study

The findings of this research represent an important contribution to other ongoing efforts to develop alternative, cheaper and sustainable sources of building materials for producing quality low-cost houses for Plateau State in particular and Nigeria at large. The results of this study have produced a quality material for incorporation in Nigerian school curriculum for teaching earth Building Construction and for students' practical in Technical Colleges. As the cost of major building materials continues to rise, without a proportionate increase in the real-income of the average Nigerian, the findings of this study represents some relief for the prospective house owner who cannot afford the cost of building material classified as standard. The findings of this study will create and open door for actualizing one of the key objectives of the Nigerian government's National Economic Empowerment and Development Strategies (NEEDS) programme and the other programme that focuses towards provision of quality housing for all its citizens.

The outcome of this study will also challenge the expertise of both practitioners and researchers in earth building practices to look inwards in their search for ways and means of developing alternative cheaper sources of quality building materials. The commercialization of the major findings of this study will translate waste (digitaria Exilis Straw (Acha) into wealth and create avenues for self-help approach to providing quality low-cost houses for Nigerians.

Conclusion

The result indicate that the nature of soil from the various study area have great influence on the blocks strength. After subjecting the blocks for test of compressive, shear, tensile and water absorption, it was observed that blocks produced from soil obtained from Barkin Ladi and Jos East Local Government Areas have higher water absorption rate. The results indicate that blocks produced from mixture of cow dung to adobe at ratio 1:4 and digitaria exilis at ratio 1:3 gave the average compressive strength of 2.05N/mm^2 and 2.04N/mm^2 at 28days while the water absorption of 21.75% at ratio 1:3 for cow dung to adobe.19.46% of water was absorbed by adobe block produced at ratio of 1:4 of digitaria exilis to adobe. The result showed average shear strength of 1.32Mpa of cow dung to adobe at ratio 1:3 and 1.77Mpa shear strength for digitaria exilis at ratio 1:4 while tensile average strength of 0.036N/mm^2 for cow dung to adobe at ratio 1:4 and 0.080N/mm^2 of digitaria exilis to adobe at ratio 1:3. This positive development towards strengths, handling, water proofing and strengths of adobe blocks suggests its usage as a low cost alternative construction material.

Recommendations

The following recommendations base on the findings of the study is made:

1. Laterite for adobe block production should first of all be sieved to remove the available vegetable impurities.
2. The mix ratio 1:4 of digitaria exilis (Acha) straw to adobe should be adopted by the local adobe builders in Plateau State.
3. Similarly, cow dung to adobe at ratio 1:3 is found to have produced reliable strength to the blocks therefore could be adopted as a new technology for alternative construction material.
4. The cow dung should properly be grounded in other to provide consistent mix when mixing with the laterite.
5. The freshly laid adobe blocks should not be left in the open field because spontaneous drying by sun could cause shrinkage.
6. The curing period of 28 days was found to have produced results with optimal strengths therefore; it could be adopted for construction of more durable adobe buildings in Plateau State.

Suggestions for Further Research

The following suggestions are made for further studies;

1. It would be important to consider other parameters such as the study of chemical analysis of cow dung to laterite soil, which is an area for further study.

2. Critical study on fibre-stabilized soil; should be researched upon to help ameliorate the housing problems facing most developing countries.
3. The study of fibres, hay, hemp, millet bagasse, coir fibres, sisal, elephant grass, bamboo palm as additives to adobe for wall construction.
4. Termite hills have the evidence to be used as walling materials, a study could also be carried out to determine its suitability as wall construction materials.

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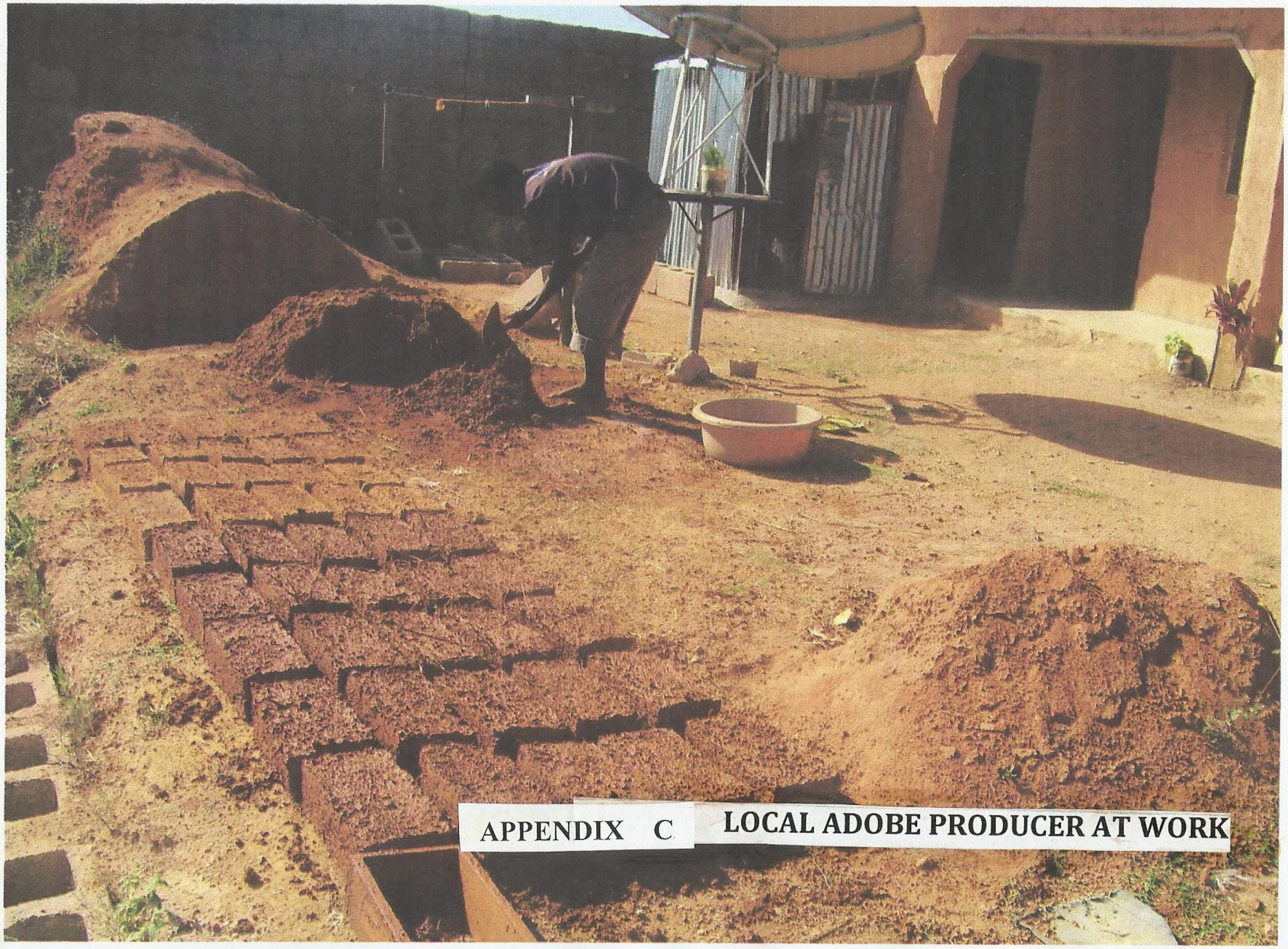
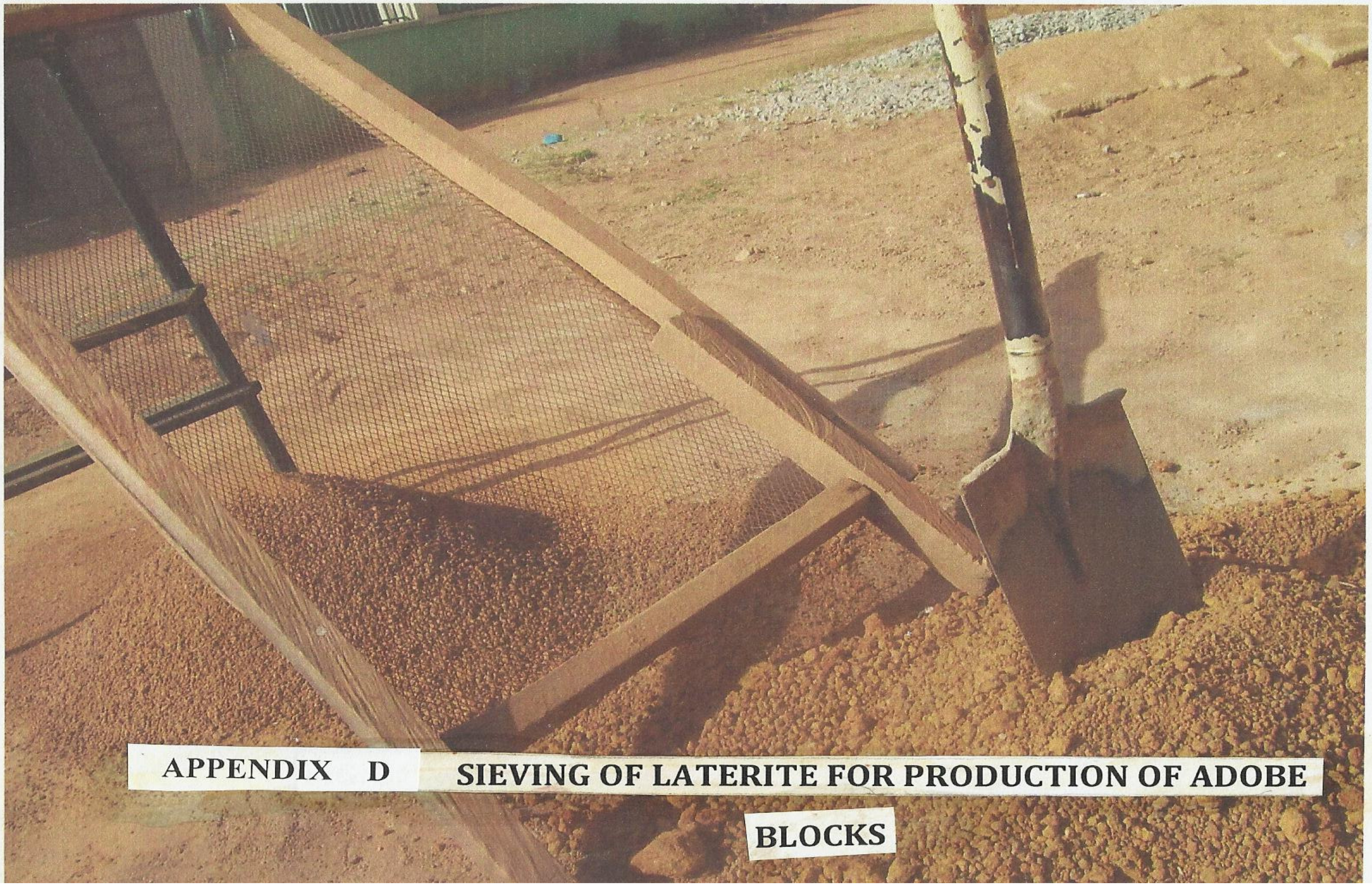
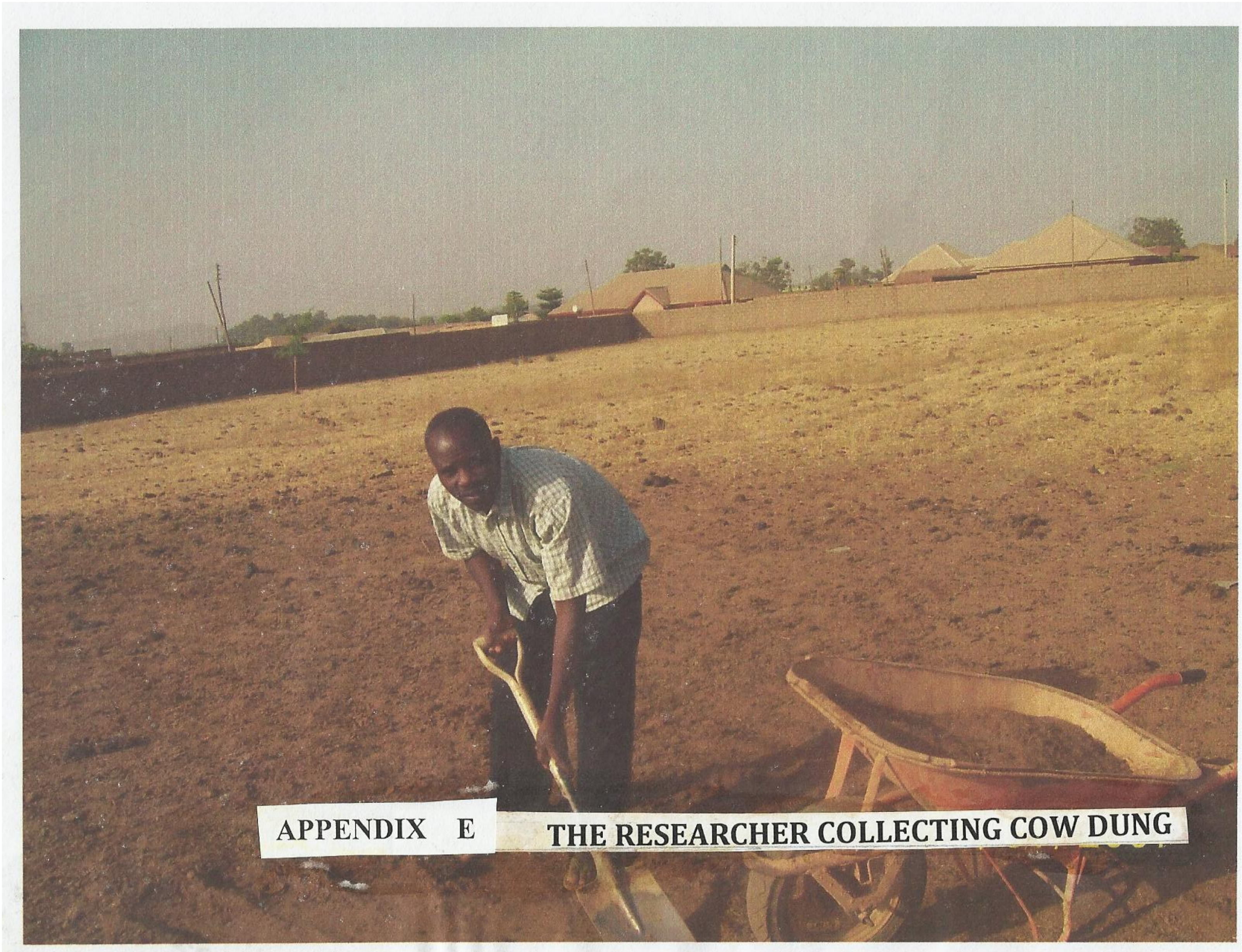


APPENDIX C LOCAL ADOBE PRODUCER AT WORK

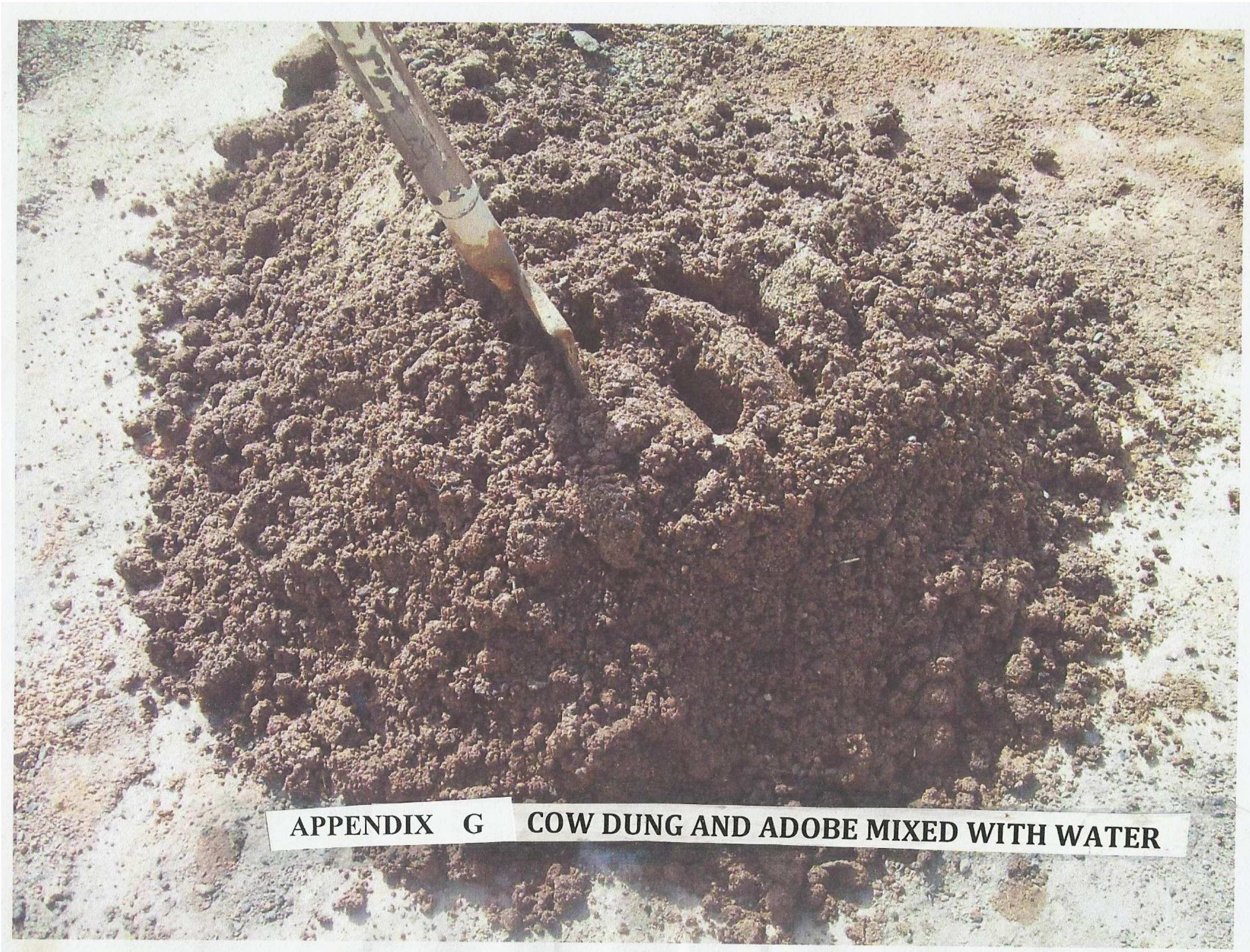


APPENDIX D SIEVING OF LATERITE FOR PRODUCTION OF ADOBE BLOCKS



APPENDIX E THE RESEARCHER COLLECTING COW DUNG

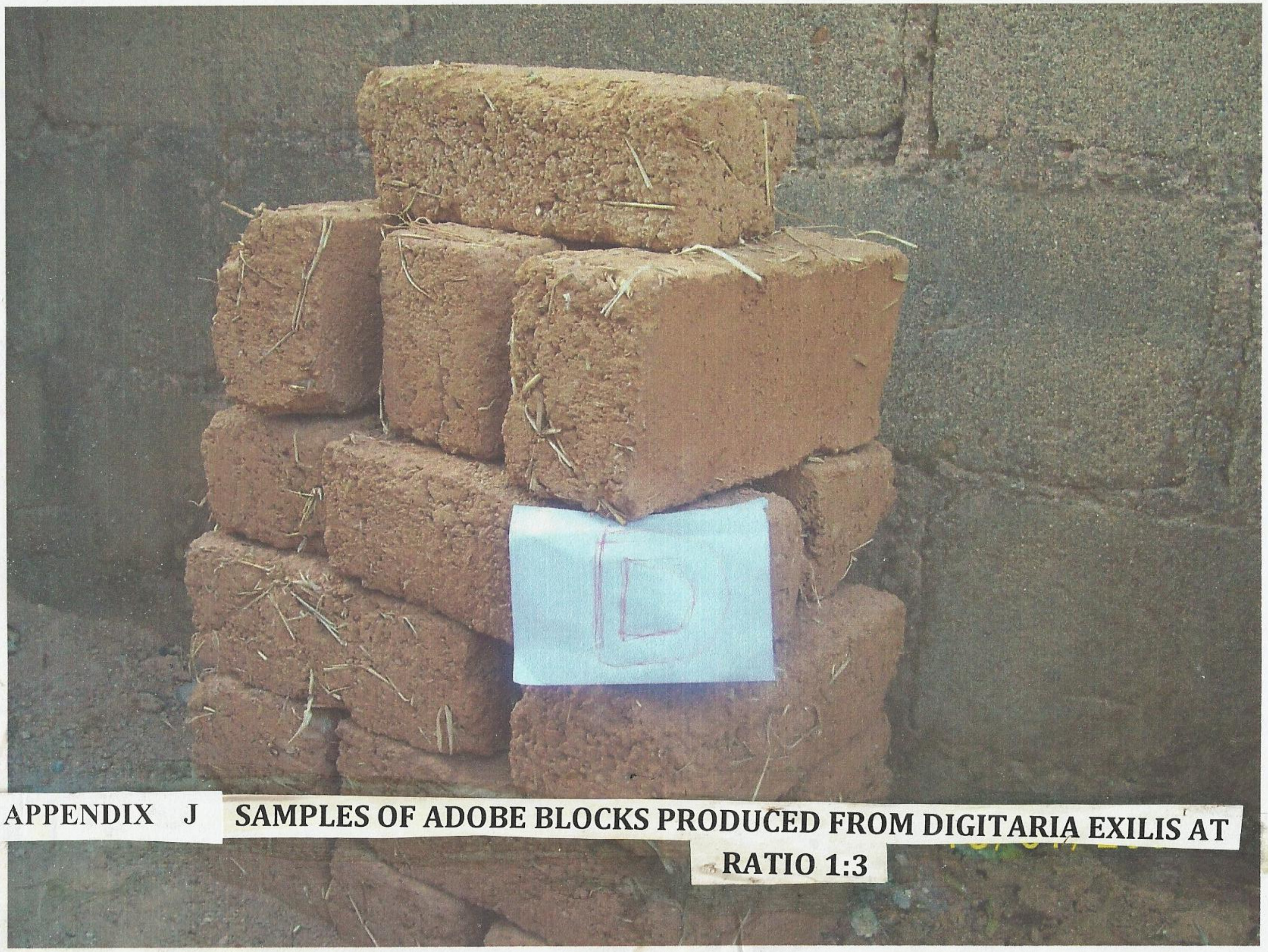
APPENDIX F RATIO OF COW DUNG TO ADOBE BEING MIXED IN DRIED STATE



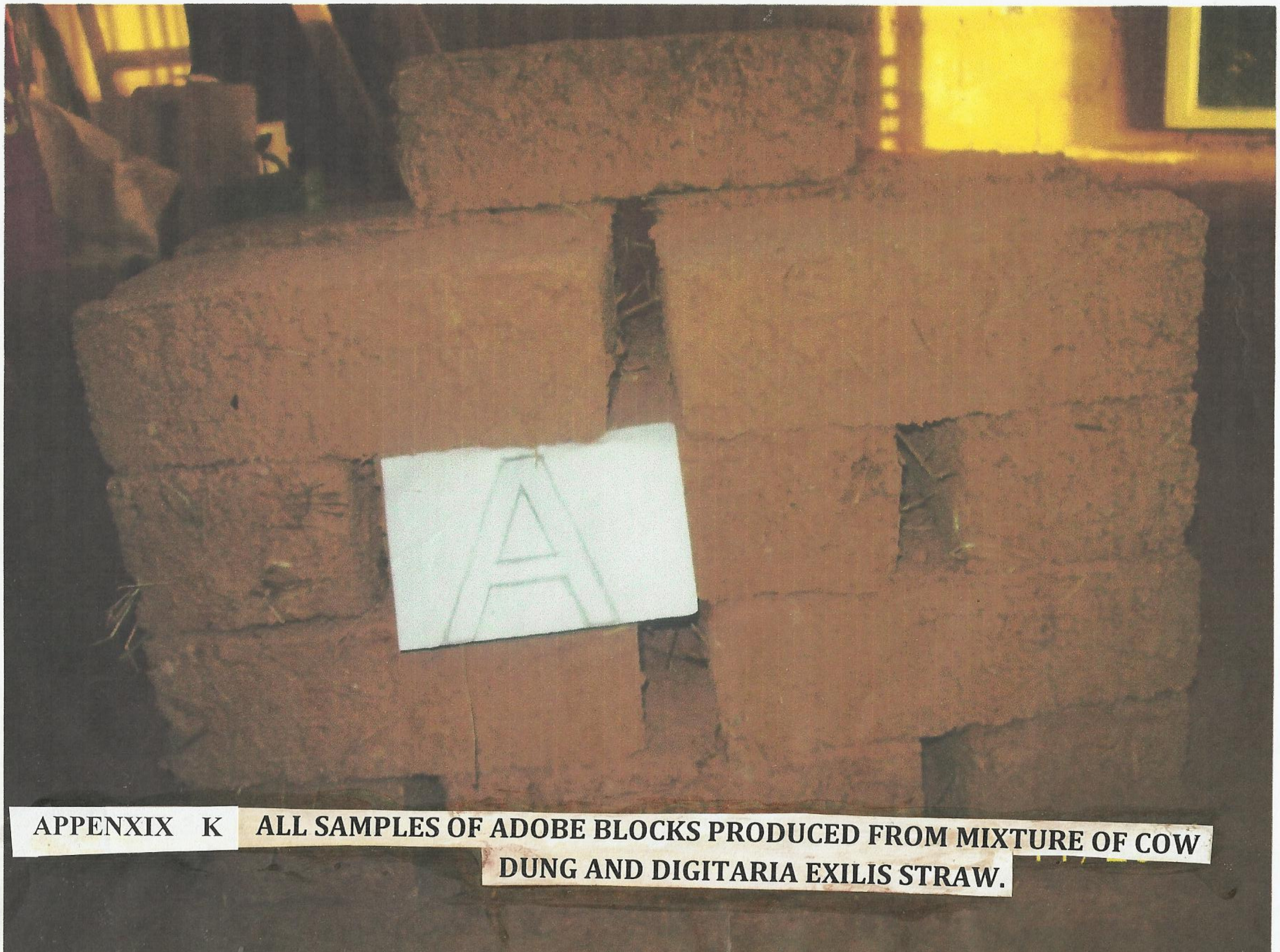
APPENDIX G COW DUNG AND ADOBE MIXED WITH WATER

APPENDIX H HEAP OF DIGITARIA EXILIS STRAW READY FOR CUTTING INTO THE REQUIRED SIZES

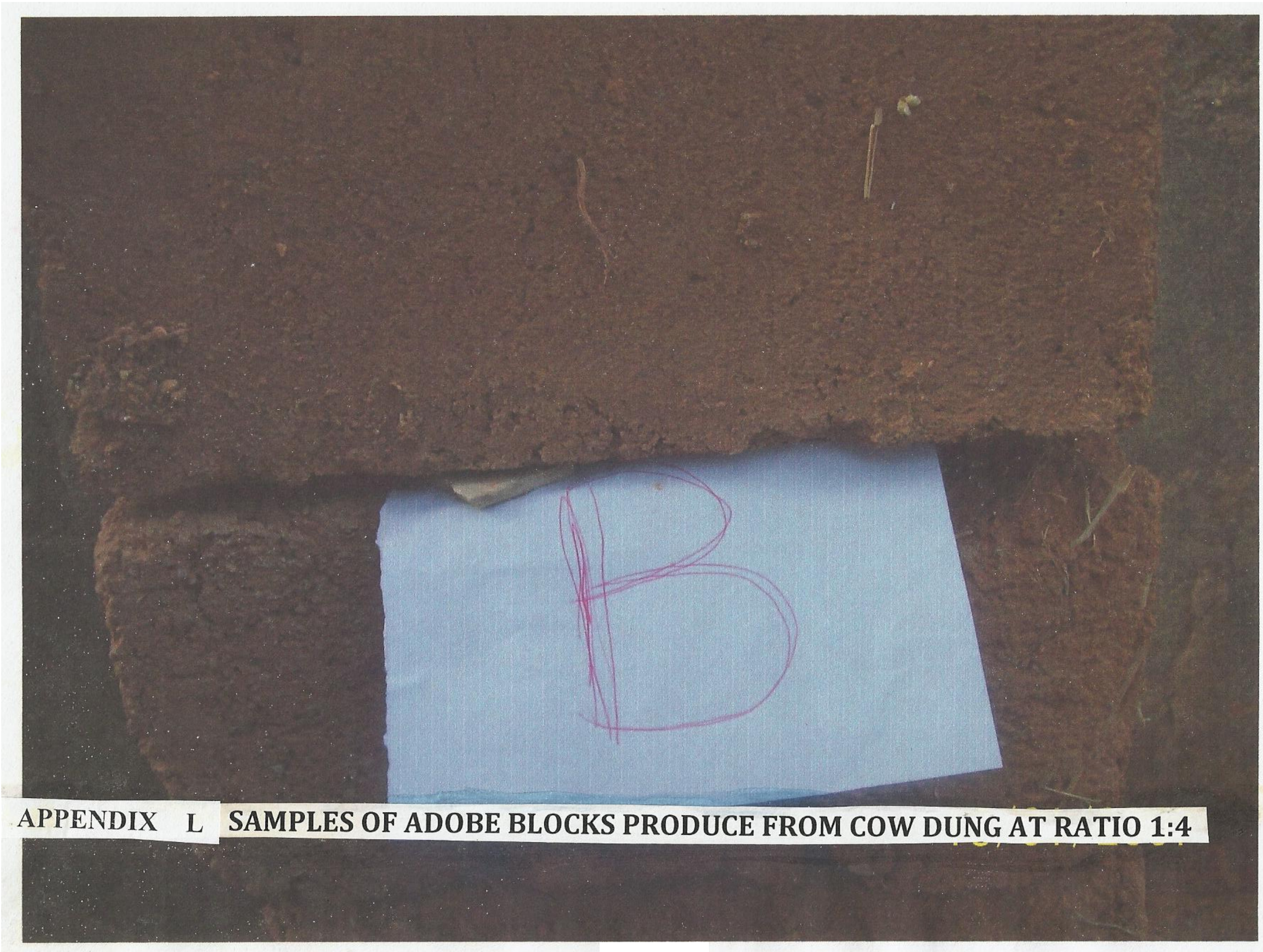
APPENDIX I SAMPLES OF ADOBE BLOCKS PRODUCED FROM DIGITARIA EXILIS UNDER CURING



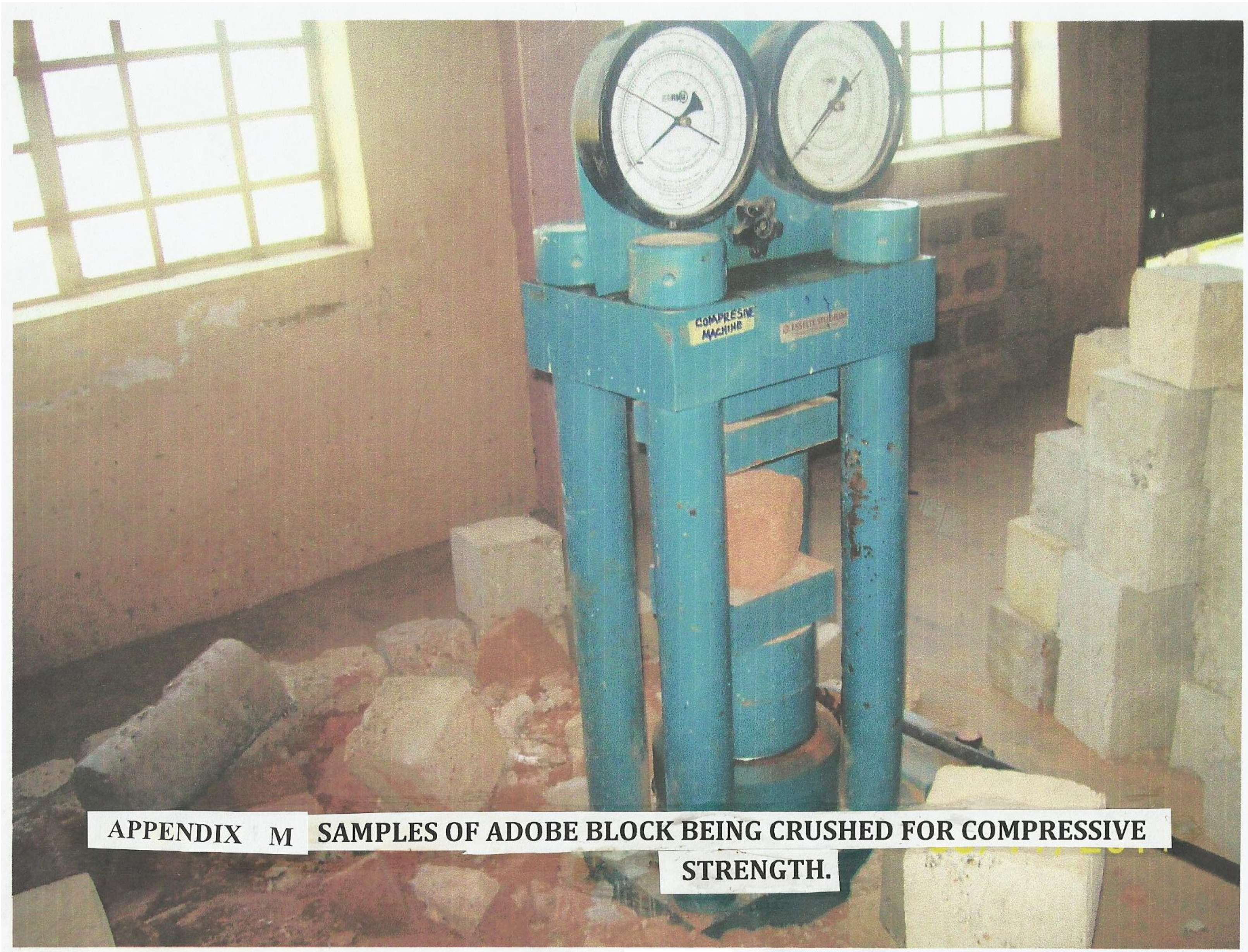
APPENDIX J SAMPLES OF ADOBE BLOCKS PRODUCED FROM DIGITARIA EXILIS AT RATIO 1:3



APPENXIX K ALL SAMPLES OF ADOBE BLOCKS PRODUCED FROM MIXTURE OF COW DUNG AND DIGITARIA EXILIS STRAW.



APPENDIX L SAMPLES OF ADOBE BLOCKS PRODUCE FROM COW DUNG AT RATIO 1:4



APPENDIX M SAMPLES OF ADOBE BLOCK BEING CRUSHED FOR COMPRESSIVE STRENGTH.