Global Scientific JOURNALS

GSJ: Volume 9, Issue 5, May 2021, Online: ISSN 2320-9186
www.globalscientificjournal.com

# COMPARATIVE STUDY OF GEOTECHNICAL PROPERTIES OF TERMITE MOUND MATERIAL AND CLAY FOR USE IN THE CONSTRUCTION OF FARM STRUCTURES

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## ABSTRACT

Termite reworked soil are common occurrence in Nigeria but unwanted in farmland and in the vicinity of structure especially those constructed with wood. The study investigates engineering properties of termite reworked soil as compared to earth material for the construction of farm structures. Three termite hills from three locations (Federal Polytechnic Bida, Bangaie and Gbanchita) were chosen. Samples were collected into empty cement bags using pick axe and shovel; the samples were air-dried and analyzed physically to determine soil texture, consistency limits, moisture content and bulk density. The mechanical properties performed were water absorption ratio, shear strength, compressive strength, specific gravity and permeability, chemical properties such as soil pH, nitrogen phosphorous, potassium, organic carbon, sodium, copper, calcium and magnesium. The results of these tests showed that, the values of the physical properties of termite reworked soil were higher than those of the earth material and properties such as shear strength, compressive strength and specific gravity values are higher in termite reworked soil than earth material. However, water absorption ratio is significantly lower in termite reworked soil than earth material, while the bulk density showed no significant difference for the two samples. The result therefore showed the importance of reworking soil by termite as indicated by it's improved engineering properties and better performance in terms of stability and durability than earth material used locally for the construction of farm structures.

Keywords: Geotechnical Properties, Termite Mound, Clay, Comparative Study, Farm Structure

## 1.0 INTRODUCTION

Farm structure is that branch of agricultural engineering that deals with the provision and maintenance of buildings and other structures within and occasionally outside the farm environment. Farm structure is a broader term which provides shelters for accommodation for man, livestock and crops.

Farm structures include existing buildings or facilities previously for non-agricultural uses but which are either remoulded or converted to be used for an agricultural purpose. Two of the criteria commonly used for the classification of farm structures are the material of construction and utilization of the structures. Mijinyawa (2002), showed that the material of construction designates all structures into earth, wooden, concrete and steel buildings or structures while the second criteria, groups them into farm houses, buildings for product storage, buildings for crop production, livestock, crop processing, equipment and supplies, and miscellaneous structures. From the definition and classification of farm structures, it's obvious that irrespective of objectives of an agricultural enterprise, farm structures are indispensable, that is no farm structures, no farm exists.

Since the early down of civilization, the strong and light material has always fascinated mankind for typical applications. Alternative building materials are those which can be use economically by replacing conventional building materials. Alternate building materials are made from locally available materials typically from earth materials, these alternate building material can be use when it meet the respective specification in the code of practice (Lauritizen, 1991).

Geotechnical is that branch of engineering that concern with the engineering behaviour of earth materials, it uses the principles of soil mechanics to investigate subsurface conditions and materials and also determine the physical, mechanical and chemical properties of earth materials (Abolarinet *al,* 2009).

Geotechnical properties of termite mound material refers to those qualities posed and characteristics exhibited by the material either in it's natural state or when used in the fabricator or construction of a structure. These properties are important because they both directly influence the strength, durability, stability and aesthetic value of the final structure in which they are used (Abe and Ola, 2008). Mijinyawa (2002), group geotechnical and geochemical properties as physical, mechanical, thermal, chemical and acoustical.

In general, geotechnical and geochemical properties are those exhibited by material which may be measured without changing or destroying the material, they includes bulk density, specific gravity, void ratio, permeability, grain size, linear shrinkage, consistency limits, compaction characteristics California Bearing Ratio (CBR), compressive strength, plasticity index and thermal analysis, (Piper, 2007).

Earth is one of the oldest materials used for building construction in rural areas. It's more frequently used in region having a dry climate and an abundance of cheap labour. Sometime, high construction labour is required and that's tends to offset its advantages of been cheap. Clay is the ideal material containing sufficient natural material that can be form an adequate binder and having a low shrinkage on drying (FAO, 2013).

Stabilized earth is an alternative building material which is significantly cheaper than using conventional brick and concrete, and is also environmental sustainable. A material that many people use in order to promote sustainable building is clay. This is the most sustainable material that many people use in construction of farm structures. The best point about clay is the lack of processing that is required to get out of the ground and use for construction (Kasali and Kraatz, 2002).



Termite are small white insect which belong to the insect order *isopteran* and group of eusocial insect which mostly feed on dead plants materials, generally in the form of wood, leaf litter, soil or animal dung, about 10% of the estimated 4,000 species are economically significant (Engel and Gilmaldi, 2005). The mounds are economically important for construction of silos in agriculture, these termite mound are built by termite workers who maintain nest to house there colony. These elaborate structures made by the workers are accomplished as a result of combination of soil, mud, chewed wood or cellulose, saliva and feaces of termite. Termite colonies consist of a fertile queen and kind (reproductive) workers (the most numerous), and soldiers (caste), (Piper, 2007).

Farm structures may be done with varieties of materials though, the selection of farm structure construction materials, is govern by functional requirement, economic conditions and condition of the environment and site. Comparative costs which are generally a determining factor in selection of materials such as; cement, and steel products meet the entire requirement for construction of farm structure than any other material, butit's high initial cost, maintenance cost, and less availability leads to the use of the other low cost and available indigenous (native) materials for farm structure construction such as stone, earth material and mud blocks (Mijinyawa, 2002).

### 1.1 Objectives

i. To determine the Engineering Properties of termite re-worked soil and earth material.
ii. To determine some of the chemical constituents of termite reworked soil and earth material.
iii. To construct brick from termite re-worked soil and earth material and compare the two for use in construction of farm structures making use of (i) and (ii) above.

### 1.2 Statement of the Problem

The materials from broken termite mounds may contain chemicals not present in undistributed clay-soil and mere disposal of the materials may not amount to efficient use of by-product of termite mound destruction. The possibility of recycling the termite mound material and introducing it into material in construction of farm structures is thus being experimented.



### 1.3 Justification

Inadequate storage structures and other farm structure have made it difficult for small scale farmer to increase agricultural production. This is as a result of high cost of construction materials. (Cements, steel, brick, concrete and metals). Compacted earth have been use in developing countries, but due to initial and maintenance costs, availability and affordability of these materials, appropriate use of farm structure may not be achieved. For these reason, there is need to ensure that the adequate farm structures needed to store agricultural products is achieved by the use of low cost, and indigenous materials which will be available, affordable and also less capital intensive.

## 2.0 LITERATURE REVIEW

Farm structure is that branch of Agricultural Engineering that deals with the provision and maintenance of buildings and other structures within an occasionally outside the farm environment. Although structures and buildings are used interchangeable, they are not exactly the same. Building refers to shelters which provide accommodation for man, livestock and crops while structures is a broader term including both shelters and non-shelters, such as bridges and fences (FAO, 2013).

2.1. **Farm Structure Construction Material**

Mijinyawa (2002), classified construction materials as follows, earth and earth products, wood and wood products, natural fibers, concrete material and miscellaneous materials or products. Wood is one of the most common constructional materials but at the same time, it is probably the most difficult to classify, select and use correctly. This difficulty is due to the great variation in the properties different species and to the influence of defects in growth and seasoning (Kasali and Kraatz, 2002).

Concretes is a mixture of cement, sand (fine aggregates) and gravel (coarse aggregates) mixed in appropriate proportions with the addition of water to form paste is the most commonly used building material in the world. It is used in majority of engineering products construction of house units, culverts, rigid pavements, gravity dams, canal lining (Lancaster and Lynne, 2005). Types of concretes, includes glass concrete, asphalt concrete, roller-compact concrete, rapid strength concrete and polymer concrete. Natural fibers include grasses, bamboos, leaves, reeds, palms, banana leaves, sisal stem and fibre, Leaves and grasses have been used more for roofs than in other parts of buildings and the rural farming community, the farmers but is made of a number of wooden columns and trusses to be covered with either leaves grasses or a mixture of both (Mijinyawa, 2002).



Earth is one of the oldest building materials. It is more frequently used in region having a dry climate and an abundance of cheap labour. Earth as a building material could be in-situ or moved from one place to another. It is the support on which supper structures rest. When removed from its' location and worked, it is used in the construction of various building component such as walls ad bricks (FAO, 2013).

Guggenheim and Martin (1999), shows that, the load bearing capacity of soils and related products are important because they determine the load that can be borne by such materials when used in building construction. Load bearing capacities depend on the soil type and the moisture content. Some values are shown in Table1.

**Table 1: Soil — Bearing Capacities**

| S/N | Soil types | Bearing capacities in kN/m2 |
|---|---|---|
| 1 | Soft, wet, pasty or muddy soil | 27 — 35 |

| | | |
|---|---|---|
| 2 | Alluvial soil, loam, sandy load | 80 — 160 |
| 3 | Sandy clay loam, moist clay | 215 — 270 |
| 4 | Compact clay ad almost dry | 215 — 270 |
| 5 | Solid clay with very fine sand | 430 |
| 6 | Dry compact clay | 320 — 540 |
| 7 | Loose sand | 160 — 270 |
| 8 | Compact sand | 215 — 320 |
| 9 | Red earth | 320 |
| I 0 | Compact gravel | 750 — 970 |
| 11 | Rock | 1700 |

Source: (Ndaliman, 2006).

Rammed earth is very useful for construction of structural walls and offer great potential as low-cost material alternatives with low embodied energy in addition; such materials are fiber brick proof (FAO, 2013).

## 2.2 **Termites**

Termites are a group of eusocial insects usually classified at the taxonomic rank of order Isopteran, ants and some bees and wasps which are all paced in the separate order Hymenoptera. They divide labour among gender lines, produce overlapping generations and take care of young collectively. Termites mostly feed on dead plant material, generally in the form of wood, leaf litter, soil, or animal dung, and about 10% of the estimated 4,000 species are economically significant as pests that can cause serious structural damage to buildings, crops or plantation forest. Termites are mostly common particularly in the subtropical and tropical regions, and their recycling of wood and other plant matter is of considerable ecological importance. As eusocial insects, termites live in colonies that, at maturity, number from several hundred to several million individuals. Colonies use a decentralized, self-organized system of activity guided by swarm intelligence to exploit food. Sources and environments that could be available to any single insect acting alone. A typical colony contains nymphs semi-mature young, workers, soldiers, and reproductive individuals of both genders, sometimes containing several egg laying queens (Engel and Krishna, 2004).

### 2.2.1 Feeding

Termites are generally group according to their feeding behaviors. Thus, the commonly used general groupings are subterranean, soil-feeding, dry wood, **damp wood and grass-eating. Of these, subterranean and** dry woods are primarily responsible for damage to human-made structures (Lauritizen, 1991).

### 2.2.2 Termite Mound

**Termite** mound is a structure built by subterranean termite. Some of the most famous examples of termite mounds can be found in Africa, where they tower up to 9 m high over the landscape, continue biting to the ecology at **the area in addition to providing a home for termite (Wisegeek, 2013). Termite mound can** be found in climates with severe temperature extremes, where daily temperature variation can be up to 30°C (54°F). Termites have a number of ways to deal with such extreme temperature difference.

### 2.2.3 Termite Nest

Termites build and maintain nest to house their colony. These are elaborate structures made using a combination of soil, mud, chewed wood/cellulose, saliva and feaces. A nest has many functions such as provide a protected living space and to collect water through condensation. There are reproductive chambers and some species even maintain fungal garden which are fed on collected plant matter, providing a nutritious mycelium on which the colony then feeds. The nests are punctuated by a maze of tunnel-like galleries that effectively provide air conditioning and control the CO2/02 balance, as well as allow the termite to move through the nest. Nests are commonly built underground, in large pieces of timber, inside fallen trees or top living trees. Some species build nest above-ground and they can develop into mounds which have grown beyond their concealing surface. (Wise geek, 2013).Termite mounds compose several compounds, some of which are listed in order of abundance in Table 2.



**Table 2: Composition of Termite Mounds**

| Composition | Percentage (%) |
|---|---|
| Si02 | 58.06 |

| | |
|---|---|
| Al2C3 | 27.72 |
| K20 | 2.59 |
| Fe203 | 1.46 |
| TiO3 | 0.87 |
| CaO | 0.20 |
| MgO | 0.36 |
| Na20 | 0.30 |

Source: (*Ndaliman, 2006*).

**2.3 Geotechnical Properties of Termite Reworked soil**

The chemical compositions of termite mound have no difference regarding to clay mineral composition. The properties of termite mound are crystalline and are very fine, they contain calcium, magnesium, aluminum considerably. The termite mounds are built using the saliva of the termite, dry leaves**,** clay soils and organic materials by the mounds builders. Although, termite mounds have clay and silt. The clay and silt are distinguished based on plasticity properties of soils as measured by the soil Alterberg limits (Guggenheim and Martin, 1999).

According to Guggenheim and Martin (1999), termite reworked soil exhibits plasticity when mixed with water in certain proportion. It appears in various colors from a dull gray to deep orange-red. The termite mound is a good binding material which is used in the construction of silos and they are relatively impermeable to water, and the termite mounds are also used where natural seals are needed such as in the cores of dams, or as a barrier in landfills against toxic seepage. Investigation by Khair, *et. al.* (1994) on chemical analysis of termite mound and adjacent soils shows that, pH and the contents of organic and Nitrogen, Phosphorus, Calcium and Magnesium where significantly higher in termite mounds compared with adjacent areas.

Abe and Ola (2008), reported on the influence of activities of termites on the engineering properties of termite reworked soils and none reworked surrounding soils from Ado-Ekiti South West Nigeria. The result of their study shows that, the specific gravity of grain and CBR of the termite reworked soils are higher than those of the surrounding soils. However, the plasticity index and linear shrinkage of termite reworked soils where significantly lower than those of surrounding soils. Furthermore, the chemical analysis of the soils showed that termite activities increase iron, manganese, magnesium, calcium, potassium, zinc and phosphorus levels of the soil.

Ndaliman (2006), shows that the earth movement activity of termites results is greater in construction of structure than normal content of clays, this is because of the anticipated transportation of the original clay content. The result of his research shows that the behavior of termite hill or mound materials when subjected to refractory test were in good comparison with the firebricks obtained elsewhere and then suggested that further improvement may be obtained when additives or other forms of rectification could be made. The activity of termite around wooden manmade structures is undesirable. As a result, the activity of termites as well as the occurrence of their mounds around manmade structures must be kept under control. Wooden components must be treated and termite mounds in close proximity to wooden structures must be broken down. In order to optimize the breaking of the mounds, a way of putting the broken pieces to practical use is being sought by assessing the suitability of termite mound material as an additive or alternative to fine aggregates in concrete. There are various admixtures, additives and aggregate alternatives used in the manufacture of concrete in order to either modify its properties and ease of handling or reduce cost in case where the quality of the concrete will not be jeopardized (Adesola, 2009).

Fall *et. al.* (2011), measure the microbial biomass of solid and stored food material in the mound of six northeastern Australian termite species using a combination of Substrate Induce Respiration (SIR) and fumigation extraction techniques. In all but one case mound soil was significantly higher than nearby surface soils. The microbial biomass of coptoterme sacinaciformis mound material. The use of river sand as an aggregate, for construction does not over rule the fact that it's sources is usually at some distance from the final user, thereby necessitating it's transportation to where it is needed, hence, it increases the depletion of construction. Also the growing concern of resource depletion and global pollution has challenged many researchers and engineers to seek and develop materials recycling on renewable resources (Afolayan and Alhasan, 2010). These new materials include the use of by products and waste materials such as termite soil in building construction.

## 2.4 **Clay and Laterite Soil**

Clay is a fine grained, firm earth material that is plastic when wet and harden when heated, consisting primarily of hydrated silicates of aluminum and widely used in making bricks, tiles, and pottery. A hardening or non-hardening material having a consistency similar to clay and used for modeling (Wikipedia, 2013). It's stiff, sticky fine-grained earth, typically an impermeable layer in the soil, it has particles smaller than silt, typically less than 0.004 mm. Laterite soil, which are widely distributed throughout the tropical and subtropical regions, generally give very good results, especially if stabilized with cement or lime. Laterite soils can be best describe as highly tropical soils containing varying proportion of iron and aluminum oxide which are present in the form of clay minerals, and usually large amount of quartz. Their colors range from ochre through red, brown or violet to black. The darker, the harder and more resistant to moisture it is some laterites harden on exposure to air. He also added that, the clay fraction is of major importance in earth construction since it binds the largest particles together. However, soil with more than 30% clay to have very high shrinkage/swelling ratios which together with their tendency to absorb moisture, may result in major cracks in the end product. High clay soils require very high proportions of stabilizer or a combination of stabilizers. Table 3 shows the soil grading suitable for construction. (Taylor, and Iydon, 1999).



**Table 3: Soils Grading Suitable for Construction**

| Uses | Clay % | Silt % | Sand % | Gravel % | Sand & Gravel % | Cobble % |
|---|---|---|---|---|---|---|
| **Rammed earth wall** | 5-20 | 10-35 | 15-35 | 35-80 | 0.30 | 0-10 |
| **Pressed soil block** | 5-25 | 15-35 | 20-40 | 40-80 | 0.20 | - |
| **Mud bricks (adobe)** | 10-30 | 10-40 | 20-50 | 50-80 | - | - |
| **Ideal general purpose mix** | 15 | 20 | 35 | 60 | 5 | - |

Source: (FAO, 2013).

Mohammed and Angela, (2009) reported that stabilized earth is an alternative building material which is significantly cheaper than using conventional brick and concrete, and also environmentally sustainable. Earth has been used as a construction material in every age, they also added that, the use of onsite as building material saves manufacturing cost, time energy, environmental pollution and transportation cost. Local construction materials have over time proven to be more superior to imported material. Most of the old bungalows in Nairobi, Kenya were built 60 to 70 years ago by Colonial occupants and have stood the test of time, without cracking or other failures; this is so because most of the materials used in their construction are local. These old house have utilized hand-dressed masonry stone walling, use of steel reinforced concrete above the door and window openings is minimal (Onwika *et. al.* 2013). Locally manufactured block board last longer end can endure moisture much better than imported board locally produced clay and concrete floor tiles are cheaper, longer lasting and more stylish than imported ceramic tiles.

Shetty, (2005) shows that, soil can be stabilized through the use of the following chemicals such as lime, Portland cement, and other pozzolans (high silica volcanic ash, rice hull ash, etc) can be used as chemical additives. Lime is most effective on clay soils, and can be used in combination with Portland cement and pozzolan. Clay's that are bentonite or highly expensive are normally unsuitable for construction without modification. The shrink and swell capacity of these soil or clays, related to their clay content can cause the block to be highly susceptible to moisture, even high humidity, however, the acid test is now the clays actually perform under compaction and even poor performance can be set by stabilization (FAO, 2013).

Clay based ceramic products can either be produced directly from a suitable clay source without the need for further addition or such products can be produced from ceramic body formulated by addition of other raw materials such as feldspar and silica sand. In either case, the mineralogical makeup of the clay component plays a dominating role in the clay component fabrication and properties of the ceramic products (Mando et al, 1994).

FAO (2013), shows that, clay/straw has been highly developed in China when grain storage bins of up to 8 m diameter 8.5 m height and 250 tonnes holding capacity have been constructed with these materials.

# 3.0 MATERIALS AND METHODS

## 3.1 Study Location

The physical and mechanic analysis was conducted in the Soil Mechanic laboratory the department of Civil Engineering and chemical analysis was conducted in the Soil and Water Engineering laboratory the department of Agricultural and Bio-environmental Engineering The Federal Polytechnic Bida while chemical analysis were conducted at National Cereal Research Institute (NCR1), Badeggi, Niger State. Bida is located geographically in the middle belt of Nigeria under guinea savannah zone and lies approximately on latitude 9.05° north and longitude 6.07° east rainfall distribution is monomodal, with average amount varying between 1000 to 1200 mm and most of the rainfalls in August or September.

## 3.2 Sample Collection

Soil sample of two different material which includes termite reworked and earth materials were collected at three different locations, they includes the Agricultural and Bio-environment Engineering Experimental Farm, The Federal Polytechnic Bida, Bangaie and Gbanchita. The termite reworked soil were collected by breaking them open with a pick axe and shovel. The samples of three locations were collected into an empty cement bags and labeled A 1, A2 and A3 respectively. About 1m depth was dogged and collect earth material using hoe and shovel the empty bag of cement were also used to collect the material and labeled as B1, B2, and B3 respectively the two samples were allowed to air dry for some days after which they were broken to the finer grade for analysis and in preparation of bricks.

Plate 1: One of the termite hills before sampling



### 3.3 Analysis of Termite Reworked soil and Earth Material

Physical, mechanical and chemical analysis were conducted on the soil samples which were collected from the termite reworked and earth material in order to ascertain the properties relevant to the construction as well as general soil properties relevant to agricultural engineering, plate 1 shows one of the termite mound before sampling.

#### 3.3.1 Physical Analysis

The physical analysis of termite reworked and earth materials was conducted to determine the moisture content, atterberg limit test, bulk density and soil texture

**Moisture Content**

The gravimetric method of determine moisture content was used to determine moisture contents of termite reworked soil and earth material, the procedure includes the following: the soil samples of termite reworked soil A and earth material B were collected from three different locations and labeled as Al, A2, and A3 and B I, B2 and B3 respectively. The soil samples were collected inside polythene bag to avoid escape of water molecules. The wet soil was weight using weighing balance and placed in a thermostical oven at 105°C for 24 hrs. The dried sample was then weight. The weight of moisture content was then determined by deducting the weight of dried soil from wet soil. The moisture content is the ratio of the weight of moisture to the weight of dried soil.

$$moisture\ comtent = \frac{mw}{ms} X\ 100 \qquad 1$$

Where mw is weight of wet soil and ms is weight of dry soil.

**Bulk Density**

The materials used in determine bulk density includes metallic core cutter, spatulas, digital weighing balance and thermostatical oven. The procedure described by Blake and Hontge (1986) was used to determine the bulk density as follows: Soil samples were taken from A and B using metallic core cuter by driven it into the soil and carefully removed by excavating soil from the side using spatula, the protrusion soil was then trimmed with spatula on the either side of the core to avoid compaction during the trimming. Soil samples were then dried in a thermostical controlled oven at 105°C for 24 hours after getting initial weight using digital weighing balance. The dried soil sample were weighted after cooling as final weight inner dimension including radius and height of the core samples were taken.



$$Bulk\ density\ (p)\ g/cm3 \ = \frac{Wsc - Wsd}{v} \qquad 2$$

Where Wsc is the weight of dried sample in (g), v is the volume in cm3 and (p) is the bulk density g/cm3

**Atterberg Limit Test**

The following materials were used in the experiment. Cone penetrometer, stop watch, 425 micrometer sieve, thermostatical controlled oven and sample container. Ian and Christopher (1999) procedure of determine atterberg limit test was used. 425 micrometer sieve was used to sieve two crushed soil samples, A representative of soil sample of a known weight was collected, cone penetrometer was set centrally and elaborate using the knob. Sieved soil sample was mixed with water until homogeneous paste was achieved wet soil sample were filled in the can and trimmed as the samples were labeled Aand B, after which initial penetration was done at the interval of 5 minutes using penetrometer after penetration a representative sample was collected and placed in a container and weighed. The sample was then placed in the oven at 105°C for 24 hours. A representative sample was collected and rubbed using palm to form a threat to get the plastic until weight and final weight was noted. After collecting values, the plastic index was then determined using this expression.

PI --- LL — PL 3

Where PI is the plasticity index, LL is the liquid limit and PL is the plastic limit.



## Soil Texture Determination

The sedimentation method described by Forth (1988) was used to determine the soil texture. The apparatus used includes test tube, test tube rack, pipette and a stop watch. As shown in plate 2. The soil texture determination was done using the following procedures. Sample and all organic matters were removed, three soil separation test were placed in the racks after cleaning and were labeled A, B and C, the soil sample was added to the soil separation tube A until it is levelled with line 15 ml, pipette was used to add lml of texture dispersing reagent sodium hexameter phosphate (Calgon) to the sample in tube A and water was added to line 45 cm separation tube A was capped and gently shake for 2 minutes making sure that all the soil sample was thoroughly mixed with water. The cap was then removed and tube A was placed in the rack and allowed to stand undisturbed for 30 seconds there after all the solution was carefully poured into the separation tube B, the remaining soil particles in tube A Was noted (sand fraction). The soil separation tube B was also left to stand for 30 minutes undisturbed, after which the remaining solution in tube B was carefully poured into tube C and the level of soil particles in tube B was noted (silt fraction). The clay fraction was obtained from the expression below

$$\% \, Sand = \frac{Reading\ in\ A}{Total\ volume} \text{x}100 \quad 4$$

$$\% \text{ Silt} = \frac{Reading\ in\ B}{Total\ volume} \text{x } 100 \quad 5$$

% clay =100 -(% sand + % silt) 6

Soil textural triangle was used to determine the soil type.

### 3.2.2 Mechanical Analysis

**Permeability Test**

Permeability was determined using constant head permeability following the test described by Smith and Smith (1998). The procedure includes the followings. A soil sample of 400 g was collected from two samples A and B, constant head was filled with water, it was then allowed to flow through soil sample and allowed to over flow and start discharge, the head different in manometer taping length of sample (L) was measured, A cross-sectional area was also noted. Diameter of piezometer (cylinder) was also taken using metre rule, a stop watch was then set, a measuring cylinder was used and collect the discharged water at interval of 30 seconds and discharged water was noted as (Q)

The coefficient of permeability K was determined directly from Darcy's equation stated below.

$$K = \frac{QL}{tAh} \quad 7$$

Where k is the permeability, A is cross-sectional area of sample, Q is the quantity of water collected, L is the distance between tapings, t is the duration of test and h is the head difference in manometers.

**Shear Strength Determination**

The materials used in determining shear strength, include shear strength test machine (model E587), cutting ring, spatula and stop watch. Direct shear box method described by Ian and Christopher (1999) was used. The shear strength test machine was set up with the necessary accessories put in place. The soil sample with the sample in it was placed on top of the carriage seated on top of the direct shear strength test machine. A vertical load was applied to the top of the sample by means of a weight. As the shear strength was predetermined in the horizontal direction. The vertical load sharing force was gradually exerted on the box. The desired vertical load of 10 g, 20 g and 30 g were applied at an intervals of 5 minutes and thereby taking the proving ring readings. The results obtained were tabulated, where compressive and shear stresses were calculated. Shear strength was calculated using Terzaghi's equation.

$$quit = CNc + yzNq + 0.5yBNy \quad 8$$

where quit is of allowable shear strength with factor of safety of 3 in kN/m2, C is the cohesion of the soil, is the unit weight of the sample in kN/m3, z is the depth of the soil sample, B is the breadth of the sample and NC + Nq + Nr are terzaghis coefficient constants. This procedure was done for sample A and B respectively.

**Casting of Bricks**.

British standard code of practice (BS 3114) was used to cast bricks by using a wood form-work of ratio 25 x 12 x 8 mm, as shown in plate 4.Representative of soil samples A and B where taken and crushed using metal, 5000 g of soil sample were weighed for sample A and B, 150 cl volume of water was added and mixed thoroughly until homogeneous paste was formed. It was then transported into the form work and cast bricks. The casted bricks were covered with polythene bag for 24 hours to avoid loss of moisture content, thereafter; the brick were exposed to sun to dry for one week to be set for compressive strength.

Plate 4: Casted Bricks

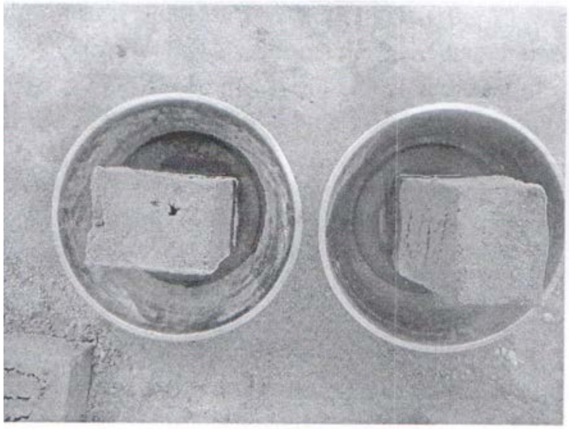

Plate 5: Determination of Water Absorption Ratio

**Compressive Strength.**

Compressive test machine (model E57) was used to crush the brick, this was done by placing the known weight brick under the crushing machine the gear was then engage, thereafter it was disengage immediately after brick start to crack and take the readings from the gauge.



**Specific Gravity**

The International Society of Soil Science (ISSS) method was used to determine specific gravity. The procedures includes digital weighing balance was used to weigh density bottle in (g) mi is density bottle + sample (g) m2 is weight of density bottle - - sample water (g) m3 and bottle + water (g) ma.

Specific gravity was then determined using the following equation

$$Gs = \frac{m2 - m1}{(m4 - m1) - (m3 - m2)} \quad 9$$

**Water Absorption Ratio**

British standard code of practice (BS 3114) was used to determine the water absorption ratio, the procedure are as follow. 250 cl water was measured using measuring cylinder and poured into 2 open cans, as shown in plate 5, bricks of two samples were then weighed using weighing balance. A stop watch was then set, two samples A and B bricks were then immersed in the water for 1 hour, after which the bricks were removed from water and measured the remaining water using cylinder. The water absorption ratio was calculated as initial volume of water — final volume of water.

### 3.3.3 Chemical Analysis

Nitrogen, phosphorous and potassium were determined from the soil samples A and B for termite re-worked soil and earth material respectively. This analysis was done in the Soil and Water Engineering Laboratory, The Federal Polytechnic Bida, International Society of Soil Science (ISSS) standard was used. The materials used in the analysis includes, universal extracting solution, pippet, filter paper, funnel, test tube, Nitrogen, phosphorous and potassium tablets. The procedures includes, the universal extracting solution was used to filled the test tube to line 7, 0.5 g spoon was then used to add four level measures of soil. It was caped and shake for two minutes, a filter paper was folded and placed in the funnel. Thereafter, the funnel was placed in the test tube, the suspension was filtered through the filter paper. The extract was then used for the analysis. Using Nitrogen, phosphorous and potassium tablets and colour charts. As shown in plate 3.

Sodium, calcium, organic carbon, magnesium and soil pH were determined at National Cereal Research Institute (NCRI) Baddegi, Niger State. The extraction of soil solution was done as follows: 5 g of soil samples A and B were weighed which has passed through 2 mm sieve into an extraction bottles and labeled A and B respectively, 50 ml of NH40 was added into the soil samples it was then shake for 15 minutes using orbit shaker, then the soil suspension was allowed to stand for 5 minutes, thereafter, the suspension was filtered using centrifuge for 10 minutes. The extract was then used to determine sodium (Na) and calcium (Ca) using flame photometer, copper (Cu) and magnesium (Mg) were determined using Atomic Absorption Spectrophotometer (AAS) (model Uv 120 — 01).

Soil pH was determined by using pH meter (model kentEil 7045). Organic carbon was also determined by titration with standardized iron solution and H2504 acid. The organic carbon was thereafter determined by using the following equations

$$O.C = \frac{(S-B)\,x\,Fe\,x\,0.003\,x\,1.33\,x\,100}{1.0\,(wt)} \quad 10$$

Where O. C is the organic carbon in %, S is the sample reading, B is the blank reading, Fe is iron solution and wt is the sample weight.

## 4.0 RESULTS AND DISCUSSION

### 4.1 Physical Properties

The physical properties of two soil samples A and B for termite reworked soil and earth material respectively examined were moisture content, atterberg limit which includes liquid limit (LL), plastic limit (PL) and plasticity index, bulk density soil texture which includes percent sound silt and clay.

Table 4 presents the physical analysis results which shows variation in moisture content, moisture is the ratio of the mass of water present in the soil sample to the mass of the soil in the sample, moisture content are the basis on which atterberg limits of a soil are established. The result indicate the average moisture content determination of termite reworked soil was found to be 12.93 % and for earth material was found to be 7.64 % the result of texture analysis indicates clay on termite reworked soil and earth material varies between sandy clay, silt clay and clay the bulk density of termite reworked soil varies between 1.537 g/cm3, to 1.619 g/cm3 and for earth material ranges between 1.364 g/cm3, to 1.425 g/cm3. Liquid limit is that moisture content at which a soil changes from the liquid state to the plastic state; it provides a means of soil classification test alongside with the plastic limit provide the range of water increment to be added to the soil sample in carrying out geotechnical investigation. The average value of liquid limit test of termite reworked soil was determined to be 30.61 % while average value of earth material was examined to be 22.89 %, the average values of plastic limit test of termite reworked soil examined was 21.33 %, while the average value of earth material was determine to be 17.57 % the plasticity index was determine by plotting a graph of plastic limit against liquid limit on the plasticity chart which enables the classification of cohesive of samples. Average value of plasticity index of sample A and B was determine to be 9.15 % and 5.31 % respectively which indicate that, the higher the cohesiveness of the soil, the higher the plasticity of the soil and the higher the percentage of clay content in the soil. Therefore, since the clay and plasticity content of the sample A is higher than the samples B, therefore, termite reworked soil have mere properties for enhancement of the construction of farm structure and probably used in water retuning structure.

Table 4: Results of the Physical Analysis of Termite Reworked Soil and Earth Material.

| **Sample** | | **Moisture content (%)** | **Atterberg Limit (%)** | | | **Soil Texture (%)** | | | **Bulk density (g/cm3)** |
|---|---|---|---|---|---|---|---|---|---|
| | | | LL | PL | PI | Sand | Silt | Clay | |
| **A** | A1 | 12.17 | 29.62 | 20.30 | 9.35 | 16.67 | 23.33 | 60.00 | 1.588 |
| | A2 | 13.81 | 30.32 | 21.24 | 9.08 | 24.67 | 23.33 | 52.00 | 1.619 |
| | A3 | 12.47 | 32.14 | 23.12 | 9.02 | 20.00 | 20.00 | 60.00 | 1.537 |
| **B** | B1 | 7.95 | 22.03 | 17.91 | 4.12 | 49.30 | 40.00 | 10.70 | 1.405 |
| | B2 | 7.31 | 21.45 | 16.30 | 5.15 | 40.60 | 39.33 | 21.33 | 1.364 |
| | B3 | 7.67 | 25.20 | 18.52 | 6.68 | 23.30 | 30.00 | 46.07 | 1.425 |

Source: Laboratory Experiment.

NB: Sample A is termite reworked soil and sample B is earth material



## Mechanical Properties

Table 5 presents the result of mechanical analysis of termite reworked soil sample A and earth material sample B, they includes specific gravity, permeability, shear strength. compressive strength and water absorption ratio. The result of specific •gravity examined for termite reworked soil varies between 2.280 g to 2.990 g and for earth material was determined to be between 1.192 g to 2.013 g shear strength of sample a ranges from straight was examined to 176.52 kN/m2 to 193.41 kN/m2 this can be attributed to the highest bulk density observed at sample A and higher specific gravity of sample A, permeability values of sample A ranges between 0.062 cm/sec to 0.077 cm/sec, sample B was determine to be 0.104 cm/sec to 0.115 cm/sec which shows that the higher the bulk density, specific gravity and shear strength of soil, the lower the permeability and the lower the water absorption ratio and the stronger the material for the construction of the farm structures.

Therefore, according to British Standard code of practice (BS 3 I 14), termite reworked soil have more geotechnical properties and have better chance as construction material over earth material. Compressive strength result determined from compressive test machine shows that, the termite reworked soil have higher strength when subjected to heavy load and can be able to withstand any load for a longer time than earth material, also the water absorption ratio of termite networked soil is less which was determined to be 95.2 cl/hr, for earth material it was examined to be 125.6 cl/hr. which shows that a structure build with termite reworked material when subjected to flooding it can withstand water for quite some time than structure with earth material.

Table 5: Result of Mechanical Analysis of Termite Reworked Soil and Earth Material.

| Sample | | Specific gravity (g) | Permeability test K(cm/sec) | Shear strength (KN/m$^2$) | Compressive Strength (KN) | Water Absorption Ratio (CL/hr.) |
|---|---|---|---|---|---|---|
| **A** | A1 | 12.17 | 29.62 | 20.30 | 9.35 | 16.67 |
| | A2 | 13.81 | 30.32 | 21.24 | 9.08 | 24.67 |
| | A3 | 12.47 | 32.14 | 23.12 | 9.02 | 20.00 |
| **B** | B1 | 7.95 | 22.03 | 17.91 | 4.12 | 49.30 |
| | B2 | 7.31 | 21.45 | 16.30 | 5.15 | 40.60 |
| | B3 | 7.67 | 25.20 | 18.52 | 6.68 | 23.30 |

Source: Laboratory Experiment.

NB: Sample A is termite reworked soil and sample B is earth material

**Chemical Properties**

The chemical properties of termite reworked soil and earth material of sample A and B respectively examined were pH, nitrogen, sodium, potassium, phosphorous, calcium, sodium, carbon, magnesium and copper.

Table 6 presents the results of chemicaranalysis of sample A and B the average pH values of sample A and B varies between 6.08 and 5.01 which indicates that earth material contain more acidity which affect the plasticity of soil and thereby weakened the strength of material and the bearing capacity. Also the organic carbon content in the soil contribute to the weakness of the material, the soil void spaces becomes more open with the presence of carbon.

**Statistical Analysis**

As shown in Tables 7 and 8, the engineering properties of termite reworked soil and earth material was significantly different (P < 0.05) in all engineering properties but did not differed (P > 0.05) in term of bulk density. However sample ti showed higher shear strength (348.48 kN/m2), compressive strength (29.65 kN) and moisture content of 12.82 % while sample t2 had higher water absorption ratio (125.67 cl/hr.) when compared to sample ti from T-test analysis, (SPSS,2006).

Table 6: Result of Chemical Analysis of Termite Reworked and Earth Materials.

| **Sample** | | **pH** | **N (Pound/Acre)** | **P (Pound /Acre)** | **K (Pound /Acre)** | **C(%)** | **Na(%)** | **Ca (%)** | **Cu (%)** | **Mg (%)** |
|---|---|---|---|---|---|---|---|---|---|---|
| **A** | A1 | 5.91 | 10 | 100 | 100 | 0.62 | 0.31 | 0.40 | 1.53 | 1.21 |
| | A2 | 6.32 | 10 | 100 | 75 | 0.91 | 0.35 | 0.37 | 1.67 | 1.10 |
| | A3 | 6.02 | 10 | 95 | 75 | 0.89 | 0.30 | 0.41 | 1.41 | 1.13 |
| **B** | B1 | 5.14 | 10 | 80 | 25 | 1.56 | 0.29 | 0.50 | 1.31 | 0.91 |
| | B2 | 5.10 | 10 | 85 | 25 | 2.52 | 0.30 | 0.31 | 1.38 | 0.39 |
| | B3 | 5.02 | 10 | 85 | 25 | 2.70 | 0.28 | 0.32 | 1.33 | 0.43 |

NB: pH is soil pH, N is Nitrogen, p is potassium, K is phosphorus, C is carbon, Ca is calcium, Na is sodium,
Cu is copper and Mg is magnesium, sample A is termite reworked soil and sample B is earth material.

Table 7: T - Test Analysis of Engineering Properties of Termite Reworked Soil and Earth Material.

| | T-TE | N | Mean | Std Dev iation | Std Error Mean |
|---|---|---|---|---|---|
| **Shear Strength** | A | 3 | 3.484E2 | 103.94667 | 60.01364 |
| | B | 3 | 1.8596E2 | 8.61905 | 4.97621 |
| **Comprehensive Strength** | A | 3 | 29.6533 | 1.34482 | 0.77643 |
| | B | 3 | 23.3000 | 1.86000 | 1.07387 |
| **Water Absorption ratio** | A | 3 | 95.1667 | 3.25320 | 1.87824 |
| | B | 3 | 1.2567E2 | 4.04145 | 2.33333 |
| **Moisture Content** | A | 3 | 12.8167 | 0.87323 | 0.50416 |
| | B | 3 | 7.6433 | 0.32083 | 0.18523 |
| **Bulk Density** | A | 3 | 1.5877 | 0.02050 | 0.01184 |
| | B | 3 | 1.2947 | 0.25985 | 0.15002 |

NB: A is Termite reworked soil and B is Earth material



Table 8: Summary of T-test Analysis for Engineering Properties of Termite Reworked Soil and Earth Material.

Samples 1, 2.

| Engineering Properties | T1 | T2 |
|---|---|---|
| **Shear Strength (kN/M$^2$)** | 348.48 ±60.01[a] | 186.96± 4.98[b] |
| **Comprehensive Strength (kN)** | 29.65 ±0.78[a] | 23.30± 1.70[b] |
| **Water Absorption ratio (cl/hr)** | 95.17± 1.88[b] | 125.67± 2.33[a] |
| **Moisture Content (%)** | 12.82± 0.50[a] | 7.64 ±0.19[b] |
| **Bulk Density (g/cm$^3$)** | 1.59± 0.01[a] | 1.30± 0.015[b] |

1 Each value is mean + S.E of 3 determinations.

2 The different letter within the row is significantly different (P< 0.05).

3 Sample T1 is termite reworked soil, T2 is earth material. a Is significant higher while b is significant lower.

## 5.0 CONCLUSIONS AND RECOMMENDATIONS

### 5.1 Conclusions

From the result obtained in the analysis, the study shows that when compare termite reworked soil and earth material as construction materials for farm structure, termite reworked soil has more advantages and safe over earth material. This is because of the high percentage of geotechnical properties such as shear strength, compressive strength, bulk density specific gravity present in both materials. The result of this research is more beneficial in the areas where conventional farm structure construction material cannot be reached; and most especially for small scale farmers who cannot afford construction materials such as cement, concrete, metal and steel etc. termite reworked soil could also serve as a better alternative construction materials because of it is durability and safety even when it is loaded with grains or any agricultural produce than wood and earth materials



### 5.2 Recommendations

From the result obtained in the analysis, the following recommendations can be reached.

1. Termite reworked soil can be used as an alternative material for the construction of farm structure, since it is readily available, less expensive, more economical than conventional construction materials in tropical regions.
2. In construction of farm structure using termite reworked soil, the geotechnical investigation should be carry out to ensure proper and adequate engineering properties present.
3. Construction of farm structure using termite reworked soil can be further investigated to find out if the strength of the material can be increased by using additives such as locust beans material locust bean is a very good binding material.

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