SOME STRUCTURAL PROPERTIES OF CONCRETE WITH FINE AGGREGATES PARTLY REPLACED BY PULVERIZED TERMITE MOUND (PTM)

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CVE/13/1059

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A project report submitted to the Department of Civil Engineering, Federal University Oye Ekiti in partial fulfillment of the requirement for the award of the B. Eng. (Hons) in Civil Engineering.

Department of Civil Engineering

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ABSTRACT

Termite are a common occurrence in Nigeria but are unwanted in farmlands and are in the vicinity of structures especially those constructed with wood. Due to the growth in population, the amount and type of waste materials have increased accordingly, many termite mound lies as waste and waiting to be exploit and the knowledge of improvising has led to many materials being used in concrete production which may provide economic advantages, and foreseeable solution to the challenges of waste management. This research work presents the results of investigation conducted to evaluate some structural properties of concrete containing pulverized termite mound (PTM) as partial replacement of fine aggregate by weight. The properties evaluated were: workability, density, compressive strength, tensile strength, moisture content, water absorption, grain analysis and chemical composition of concrete with PTM specimen. The fine aggregate fraction of the concrete was partially replaced with PTM up to 50% at interval of 10% by weight. The results showed that (i) the use of PTM to partially replaced the fine aggregate in concrete resulted in harsh concrete with low workability, (ii) concrete with PTM as partial replacement of fine aggregate up to 50% developed densities, that can be used for normal concrete application, (iii) concrete with PTM as partial replacement of fine aggregates up to 50% increase in compressive strength compared to the control specimen meanwhile it decrease in tensile strength compare to its control specimen. From the results, it can be concluded that as the increment in the replacement occurs, the workability reduces, compressive strength increases and the tensile strength decreases.

DEDICATION

I dedicate this work to GOD almighty my creator, my strong pillar, my source of inspiration, the reason behind my breath... author of wisdom, knowledge, and understanding. I also dedicate this report to my parents, family, siblings and all well-wishers for their support and their encouragement.

CERTIFICATION

This is to certify that this proposal was written by **DARAMOLA DAMILOLA DAVID (CVE/13/1059)** under my supervision and is approved for its contribution to knowledge and literary presentation. All sources of information are specifically acknowledged by means of references, in partial requirements for the award of Bachelor of Engineering (B.Eng.) degree in Civil Engineering, Federal University Oye Ekiti.

26-3-19

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LIST OF ABBREVIATION

ASTM:	American Society Testing Materials
BS:	British Standard
CTM:	Calcined Termite mound
OPC:	Ordinary Portland Cement
PTM:	Pulverized Termite Mound
TMM:	Termite Mound Method
USCS:	Unified Soil Classification System

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CHAPTER ONE

INTRODUCTION

1.1 General Problem

The activity of termites around wooden manmade structures is undesirable. As a result, the activities 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 cases where the quality of the concrete will not be jeopardized.

Roman concrete (or *Opus caementicium)* was made from quicklime, pozzolanic ash or pozzolana, and an aggregate of pumice during the Roman Empire. Its widespread use in many Roman structures, a major event in the history of architecture termed the Concrete Revolution, freed Roman construction from the restrictions of stone and brick material and allowed for revolutionarily new designs both in terms of structural complexity and dimension (Lancaster, 2005).

1.1.1 Concrete

According to the Concrete Wikipedia, (2009) Concrete is a construction material composed of cement, aggregate (normally a coarse aggregate such as gravel, or granite, and a fine aggregate such as sand), water, and sometimes chemical admixtures. The word concrete comes from the Latin word *"concretus"* (meaning compact or condensed). Concrete solidifies and hardens after mixing with water and placement due to a chemical process known as hydration. The water reacts with the cement, which bonds the other components together, eventually creating a stone-like material. Concrete is used to make foundations, architectural structures, brick and block walls, pavements, roads, bridges, parking structures, and footings for gates, fences and poles.

1.1.2. Composition of Concrete

Many types of concrete can be created by varying the proportions of the main components which are cement, fine aggregates, coarse aggregates and water, the addition of admixtures, and the use of alternative aggregates. The mix design depends on the type of structure being built, how the concrete will be mixed and delivered, and how it will be placed to form this structure.

1.1.3. Cement

Portland cement is the most common type of cement in general usage. It consists of a mixture of oxides of calcium, silicon and aluminum. Portland cement and similar materials are made by heating limestone with clay, and grinding this product (called clinker) with gypsum (Concrete Wikipedia, 2009).

Termite mound material and lime has been used as partial replacement of cement in plastering and results showed that the compressive strength of the mortar cubes increases with age and decreases with increasing percentage replacement of cement with lime and termite hill (Olusola et al. 2006).

1.1.4. Water

Combining water with a cementitious material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it, and allows it to flow more easily. Less water in the cement paste will yield a stronger, more durable concrete; more water will give an easier-flowing concrete with a higher slump. Impure water used to make concrete can cause problems when setting or in causing premature failure of the structure. Hydration involves many different reactions, often occurring at the same time (Concrete Wikipedia, 2009).

1.1.5. Aggregates

Fine and coarse aggregates, consisting of sand, natural gravel and crushed stone make up the bulk of a concrete mixture. Recycled aggregates may be used as partial replacements of natural aggregates, while a number of manufactured aggregates, including air-cooled blast furnace slag and bottom ash are also permitted. Decorative stones such as quartzite, small river stones or crushed glass are sometimes added to the surface of concrete for a decorative finish (Concrete Wikipedia, 2009).

1.1.6. Types 0f Concrete

The design of a concrete, or the way the weights of the components of a concrete is determined, is specified by the requirements of the project and the various local building codes and regulations. As a result of this, mix designs can be complex and many factors need to be taken into account, from the cost of the various additives and aggregates, to the tradeoffs between, the "slump" for easy mixing and placement and ultimate performance. Various types of concrete have been developed for specialist application and have become known.

a) **Regular Concrete**: This concrete can be produced to yield a varying strength from about 10 MPa to about 40 MPa, depending on the purpose, ranging from blinding to structural concrete respectively (Concrete Wikipedia, 2009)

b) **High-Strength Concrete:** High-strength concrete has a compressive strength generally greater than 40 MPa. High-strength concrete is made by lowering the water cement (W/C) ratio to 0.35 or lower. Often silica fume is added to prevent the formation of free calcium hydroxide crystals in the cement matrix, which might reduce the strength at the cementaggregate bond (Concrete Wikipedia, 2009).

c) **Stamped Concrete:** Stamped concrete is an architectural concrete which has a superior surface finish (Concrete Wikipedia, 2009).

d) **High-Performance Concrete**: High- performance concrete (HPC) and Ultrahigh-performance concrete are relatively new terms used to describe concrete that confound to a set of standards above those of the most common applications, but not limited to strength. While all high-strength concrete is also high-performance, not all high-performance concrete is high-strength. Some examples of such standards currently used in relation to HPC are: Ease of placement, compaction without segregation, early age strength, Permeability, density, heat of hydration, and volume stability (Concrete Wikipedia, 2009).

e) **Shot Crete:** Compressed air is used to shoot concrete onto (or into) a frame or structure. Shot Crete is frequently used against vertical soil or rock surfaces, as it eliminates the need for formwork. It is sometimes used for rock support, especially in tunneling. Shot Crete is also used for applications where seepage is an issue to limit the amount of water entering a construction site due to a high water table or other subterranean sources (Concrete Wikipedia, 2009).

f) **Pervious Concrete:** Pervious concrete contains a network of holes or voids, to allow air or water to move through the concrete. This allows water to drain naturally through it, and can both remove the normal surface-water .drainage infrastructure, and allow replenishment of groundwater when conventional concrete does not. It is formed by leaving out some or all of the fine aggregate (fines). The remaining large aggregate then is bound by a relatively small amount of Portland cement. When set, typically between 15% and 25% of the concrete volume is voids, allowing water to drain through the concrete.

g) **Polymer Concrete:** Polymer concrete is concrete which uses polymers to bind the aggregate. Polymer concrete can gain a lot of strength in a short amount of time.

Polymer concrete is generally more expensive than conventional concretes (Concrete Wikipedia, 2009).

h) **Mudcrete** is a structural material (employed, for example, as a basecourse in road construction) made of mixing mud (usually marine mud) with sand and concrete or cement.

i) It is used as a cheaper and more sustainable alternative to rock fill (Association of Consulting Engineers New Zealand, 2007).

1.1.7 Other Mixtures

On-going research into alternative mixtures and constituents has identified potential mixtures that promise radically different properties and characteristics. One university has identified a mixture with much smaller crack propagation that does not suffer the usual cracking and subsequent loss of strength at high levels of tensile strain. Researchers have been able to take mixtures beyond 3 percent strain, past the more typical 0.1% point at which failure occurs (physorg, 2009).

Other institutions have identified magnesium silicate (talc) as an alternative ingredient to replace Portland cement in the mix. This avoids the usual high-temperature production process that is very energy and greenhouse-gas intensive and actually absorbs carbon dioxide while it cures (Jha, 2008).

1.1.8 Concrete Production

The processes used vary dramatically, from the use of hand tools to heavy industry, but result in the concrete being placed where it cures into a final form. Thorough mixing is essential for the production of uniform, high quality concrete. Separate paste mixing has shown that the mixing of cement and water into a paste before combining these materials with aggregates can increase the compressive strength of the resulting concrete (Gary, 1989). The paste is generally mixed at a w/cm (water to cement ratio) of 0.30 to 0.45 by mass. Workability is the ability of a fresh (plastic) concrete mix to fill the form/mold properly with the desired work (vibration) and without reducing the concrete's quality. It depends on water content, aggregate (shape and size distribution), cementitious content and age (level of hydration), and can be modified by adding chemical admixtures (Concrete Wikipedia, 2009).

1.1.9 Properties of Concrete

Concrete has relatively high compressive strength, but significantly lower tensile strength. It is fair to assume that a concrete samples tensile strength is about 10%- 15% of its compressive strength (American Concrete Institute Committee, 2008). The modulus of elasticity of concrete is a function of the modulus of elasticity of the aggregates and the cement matrix and their relative proportions. The modulus of elasticity of concrete is relatively constant at low stress levels but starts decreasing at higher stress levels as matrix cracking develop. Concrete has a very low coefficient of thermal expansion. All concrete structures will crack to some extent which may be due to shrinkage or tension.

1.1.10 Damage to Concrete

Concrete is susceptible to chemical damage and physical damage. Some of the types of damage are outlined below:

CARBONATION: carbon dioxide from air can reacts with the calcium hydroxide in concrete to form calcium carbonate. This is essentially the reversal of the chemical process of calcination of lime taking in a cement kiln. Carbonation of concrete is a slow and continuous process progressing from the the outer surface inward, but slows down with increasing diffusion depth. Carbonation has two effects: it increases mechanical strength of concrete, but it also decreases alkalinity, which is essential for corrosion Prevention of the reinforcement steel.

ACTION OF CHLORIDES: chlorides, popularly called calcium chlorides, have been used to shorten the setting time of concrete (United states Federal Highway Administration, 2007). However, calcium chloride and to a lesser extent sodium chlorides has been shown to leach calcium hydroxides and cause chemical changes in Portland cement, leading to loss of strength (Wanga et al, 2005) as well as attacking the steel reinforcement present in most concrete.

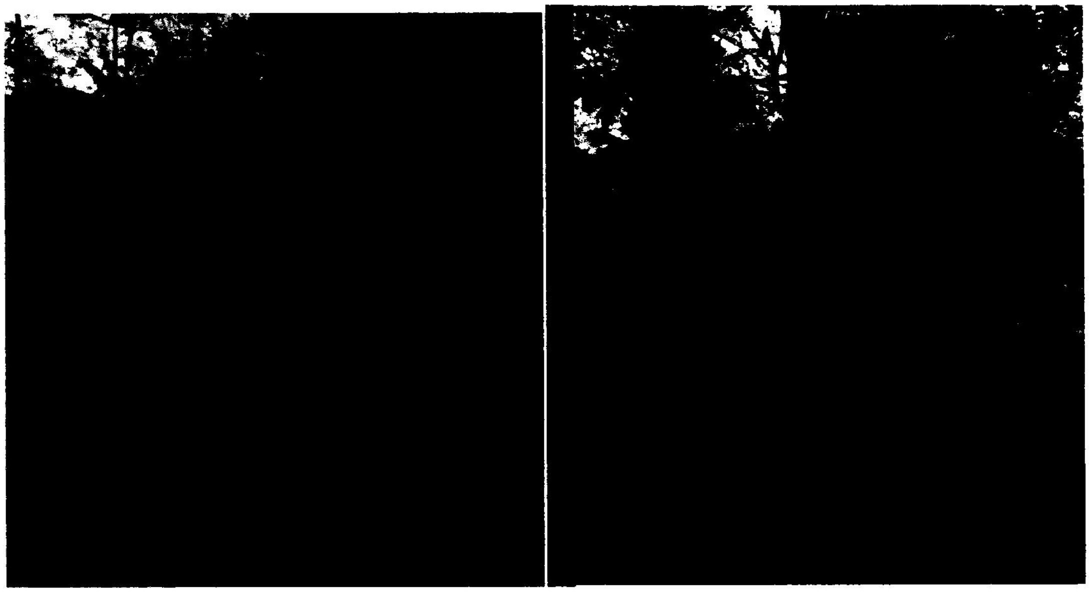
SULPHATES: Sulphates in solution in contact with concrete can cause chemical changes to the cement, which can cause significant microstructural effects leading to the weakening of the cement binder (concrete Wikipedia, 2009).

DISTILLATE WATER: Distillate water sourced from steam or hot water, can wash out calcium content in concrete, leaving the concrete is brittle condition (concrete Wikipedia, 2009)

PHYSICAL DAMAGE: damage can occur during the casting and de-shuttering processes. For instance, the corners of beams can be damaged during the removal of shuttering because they are less effectively compacted by means of vibration. Other physical damage can be caused by the use of steel shuttering without base plates. The steel shuttering pinches the top surface of a concrete slab due to the weight of the next slab being constructed (Concrete Wikipedia, 2009).

1.1.11. Termites

Termites are a group of eusocial insects usually classified at the taxonomic rank of order *Isoptera.* Along with ants and some bees and wasps which are all placed in the separate order *Hymenoptera,* termites 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 forests.



Plates 1.1: The natural termite mound. Showing its abundance in nature

Termites are major detritivores, particularly in the subtropical and tropical regions, and their recycling of wood and other plant matter is of considerable ecological importance (Termite Wikipedia, *2(09)*. 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 not 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.

Feeding: Termites are generally grouped according to their feeding behaviour. Thus. the commonly used general groupings are subterranean, soil-feeding, drywood, Damp wood, and grass-eating. Of these, subterraneans and drywoods are primarily responsible for damage to human-made structures.

Nests: Termite workers build and maintain nests to house their colony. These are elaborate structures made using a combination of soil, mud, chewed wood/cellulose, saliva, and faeces. A nest has many functions such as to provide a protected living space and to collect water through condensation. There are reproductive chambers and some species even maintain fungal gardens 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 CO~02 balance, as well as allow the termites to move through the nest. Nests are commonly built underground, in large pieces of timber, inside fallen trees or atop living trees. Some species build nests aboveground, and they can develop into mounds which are above ground nests that have grown beyond their concealing surface. Termite mounds compose several compounds, some of which are listed in order of abundance in Table 2.1

Chemical composition	Percentages (%)
SiO	58.06
AhO3	27.72
K2O3	2.56
FeO3	1.49
TiO3	0.87
CaO	0.20
MgO	0.36
Na2O	0.30

Figure 1.1: Chemical Analysis (Ndaliman, 2006)

Damage to Timber: Due to their wood-eating habits, many termite species can do great damage to unprotected buildings and other wooden structures. Their habit of remaining concealed often results in their presence being undetected until the timbers are severely damaged and exhibit surface changes. Once termites have entered a building, they do not limit themselves to wood; they also damage paper, cloth, carpets, and other cellulosic materials. Particles taken from soft plastics, plaster, rubber, and sealants such as silicone rubber and acrylics are often employed in construction (Termite Wikipedia, 2009).

1.1.12. Definition of Terms

Termite: Termites are a group of social insects usually classified at the taxonomic rank of Order *Isoptera*. 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 forests (Termite Wikipedia, 2009).

Termite Mound: A termite mound (also termitaria) is an above-ground termite nest which has grown beyond its initially concealing earth surface (Termite Wikipedia, 2009).

Concrete: Concrete is a construction material composed of cement (commonly Portland cement) as well as other cementitious materials such as fly ash and slag cement, aggregate (generally a coarse aggregate such as gravel, limestone, or granite, plus a fine aggregate such as sand), water, and chemical admixtures (Concrete Wikipedia, 2009).

Concrete Admixtures: Admixtures are chemical materials in the form of powder or fluids that are added to the concrete to give it certain characteristics not obtainable with plain concrete mixes. In normal use, admixture dosages are less than 5% by mass of cement, and are added to the concrete at the time of mixing (concrete Wikipedia, 2009).

POZZOLAN: a pozzolan is a material which, when combined with calcium hydroxide, exhibits cementitious properties. Pozzolan are commonly used as an addition to portland cement concrete mixtures to increase the long-term strength and other material properties of portland cement concrete and in some cases reduce the material cost of concrete. Pozzolans are primarily vitreous siliceous materials which reacts with calcium hydroxide to form calcium silicates; other cementitious materials may also be formed depending on the constituent of the pozzolan (pozzolan Wikipedia, 2009).

1.2 Statement of the Problem

Concrete production is based largely on the availability of its constituent materials (Cement, sand and coarse aggregate). Due to the high level of use of concrete in construction industries, the material consumption in the usage of concrete has increased drastically. The cost of which has risen astronomically over the past few years, this led to the continuous increase in the cost of construction. Not only has construction cost increased, but the quality of construction is also decreasing. This is one of the major problems the construction industry is facing. This problem of high rate of material consumption in the usage of concrete has necessitated research into the use of alternative materials especially those that are available locally which can replace conventional ones used in concrete production. Due to the growth in population, the amount and type of waste materials have increased accordingly, many termite mound lies as waste and waiting to be exploit and the knowledge of improvising has led to many materials being used in concrete production which may provide economic advantages, and foreseeable solution to the challenges of waste management.

1.3. Aim of the Study

The aim of the study is to determine the structural analysis of using termite mound materials as alternative fine aggregates in concrete preparation.

1.4. Objectives of the Study

This study, when completed will make the following contributions to the knowledge of termite mound properties and concrete technology.

a) To determine some of the chemical constituents of termite mound material as they vary with those of undisturbed clay-soil deposits.
b) To determine the workability of the concrete.
c) To determine the specific gravity of the termite mound.
d) To determine the moisture content of the termite mound.
e) To determine the compressive strength of termite mound.
f) To determine the tensile strength of the concrete.
g) To use the above data to make a sound Engineering judgment.

1.5. *Research Questions*

The answers to the following questions will be determined at the completion of the study:

a) What are the physical, mechanical and chemical properties of the soil that forms a termite mound?
b) How do the physical and chemical properties of soils in termite mounds vary with those of undisturbed clay-soil deposits?

c) What will be the strength of concrete produced by substituting fine aggregates with termite mound material during preparation?

d) Is it reasonable to use termite mound material as alternative aggregate to concrete by partial or full replacement of sand?

e) If yes, at what proportion can it be used that the concrete would retain its structural competence and its environmental friendly?

f) What positive or negative impact does it have on concrete production?

1.6. Scope of Work

Within the context of this work which is to determine the compressive and tensile strength of the concrete containing pulverized termite mound as a partial replacement of fine Aggregate at an interval of 10% up to 50%. Hence the investigation carried out is limited to compressive and tensile strength of the concrete with the chemical Analysis and some other experiments to determine it physical properties.

1.7 Significance of the Study

This research would help determine the extent at which Pulverized Termite mound would replace fine Aggregate (sand) without reducing its structural competence. Thus, this would;

1. Provide an alternative to the constituents of concrete, sand to be precise.
2. Increase waste product use in concrete production.
3. Reduce environmental wastage and promote sustainable development.

1.8. Limitations

The results of various works carried out on this particular research shows that, the compressive strength was carried out only for 7, 14, 28 days, this means that compressive strength for 60 and 90 days was not carried out, hence sound Engineering judgment cannot be made on this results. Moreover, the tensile strength test was not carried out. All these will be taken into consideration in this report.

CHAPTER TWO

LITERATURE REVIEW

2.1 Background

The role concrete plays in our modern society can be found in structures such as buildings, roads, bridges, dams etc. The ease with which it can be formed into different sizes and shapes makes it a popular and widely patronized construction material. The correct proportion of raw materials, mixing, placement and curing are needed in order to obtain concrete with optimum properties.

Several studies utilizing industrial and agricultural wastes in concrete production have been carried out. This is geared towards reducing environmental pollution that may arise as a result of too many wastes thereby reducing the cost of concrete production and the possibility of a concrete with superior qualities. Likewise natural soils and clays have been used in natural or modified state for concrete production with advantages of reduced environmental pollution and cost.

Termite mounds are heaped pile of earth built by termites and are distributed all over the world from 47° Northern latitude to 47° Southern latitude. They are extremely abundant in the tropical rain forest. The nature of the termite mound properties depends on the complexity of the social organization of the termites, diet, biology and environmental factors on the site. The two types of termites are the wood dwelling termites that lives in fresh or dead wood in which also they build their nests and the subterranean termites that lives in soil which is connected with the ground and its necessary for the normal life and dwelling of the colony.

The nest of the subterranean termites are certainly the most admired natural structures that can reach 6 m in height and 4 m wide at the base, but towers built by some of the African Macrotermes species can be even up to 9 m high.

2.2 Literature Review

Laterite is often used to describe the clinkered siliconized clay material. According to Amu *et al.* (2011), it could be described as material with no reasonable constant properties while Villan-Co Chin *et al.* (2003) and Amu *et al.* (2011) described it as a red friable clay surface, a very hard homogenous vescular massive clinker-like material with a framework of red hydrated ferric oxides of vescular infill of soft aluminum oxides of yellowish color. Villain- Cocina *et al.* (2003) opined that mechanical stability is an important factor that should be considered in the use of lateritic materials. On the other hand, mechanical instability may manifest in form of remoulding and recasting and breakdown of cementation and structure. The mechanical instability can affect engineering properties of laterite, such as particle size, Atterberg's limits, moisture content, grain size among others which in turns affect the strength of laterized products. (Middendorf *et al.*, 2003 and Day, 2003).

These properties can however be improved through stabilization in order to improve the characteristics and strength. O'Flaherty (2002), Villain-Cocina *et al.* (2003) and Amu *et al.* (2011) described soil stabilization as any treatment applied to a soil to improve its strength. Different methods have been used in laterite stabilization in recent years, mechanical and chemical stabilization being the two most popular methods in operation all over the world.

It has also been established by Lasisi and Osunade (1984) that the finer the grain size of lateritic soils, the higher the compressive strength of the unstabilized cubes made from such soils. That also reported that the possible formation processes form a factor in the strength determination and that the compressive strength of lateritic soils is dependent on the source from which they were collected.

In a study on the effect of mix proportion and reinforcement size on the anchorage bond stress of laterized concrete, Osunade and Babalola, (1991) established that both mix proportion and the size of reinforcement have a significant effect on the anchorage bond stress of laterized concrete specimens. The richer the mix proportion, in terms of cement content, the higher the anchorage bond stress of laterized concrete (Osunade and Babalola, 1991). Also, the anchorage bond stress between plain round steel reinforcement and laterized concrete increases with increase in the size of reinforcement used.

The workability of a concrete is a measure of its consistency or its fluidity. According to (Muthusamy and Kamaruzaman, 2012), there was fall in the slump as the proportion of laterite as coarse aggregate rises. This finding is illustrated by a bar chart which shows a continuous decline in slump as the proportion of laterite increased.

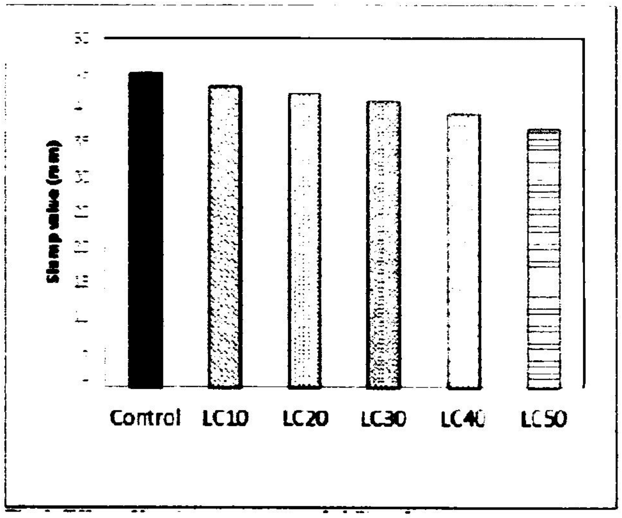


Figure 2.1: Effect of Laterite content on workability of concrete (Muthusamy and Kamaruzaman, 2012)

Laterite was used as sand substitute in concrete by (Udeoyo, et al., 2006) and their investigation showed that an enhancement in workability was observed as the proportion of laterite increased in the concrete. Figure 2 shows that at higher replacement of sand by laterite, the concrete became more workable.

Alawode and Idowu (2011) investigated water-cement ratio effect on laterised concrete workability. Balogun and Adepegba (1982) made a statement for their study that provided the proportion of laterite does not exceed 50percent, the mix proportion applicable for structural use of laterised concrete is 1:1½:3 with a water cement ratio of 0.65.

The study by Osunade (1994) found out that increase in shear and tensile strengths of laterized concrete was obtained as the grain-size-range and curing ages increased. Also, greater values of shear and tensile strengths were obtained for rectangular specimens than those obtained for cylinders. Stabilized and unstabilized lateritic soils have been reinforced with different reinforcements (e.g. rope, grass, sawdust, etc.) and results have generally shown that performance characteristics of lateritic soils can greatly be improved using such reinforcements.

Concerning compressive strength of laterised concrete, a statement made by (Nevile, 1995) states that laterised concrete cannot give better compressive strength than 10Mpa. This statement was also validated by (Oyekan and Balogun, 2000) who concluded that laterite produces a poor concrete. However, other studies have shown that this assertion is not true. The influence of laterite proportion on compressive strength.

According to (Muthusamy and Kamaruzaman, 2012), 10percent laterite aggregate replacement of coarse aggregate can yield a comparable with that of normal concrete. They also added that 30percent replacement exhibited the targeted strength of 30Mpa. Another study states that the existence of coarse grained quality laterite can enhance some properties of laterised concrete (Olutage, et al., 2013).

The compressive strength of laterite concrete increased with curing age and falls with increase in proportion of laterite (Udeoyo, et al., 2006). Figure 4 gives the of strength of laterised concrete as that of the normal concrete of similar age. Table 2 shows compressive strength of latersied concrete (Udeoyo, et al., 2006). The trend shows that all LATCON cubes attained above 70percent of their 28 days strength at 7 days.

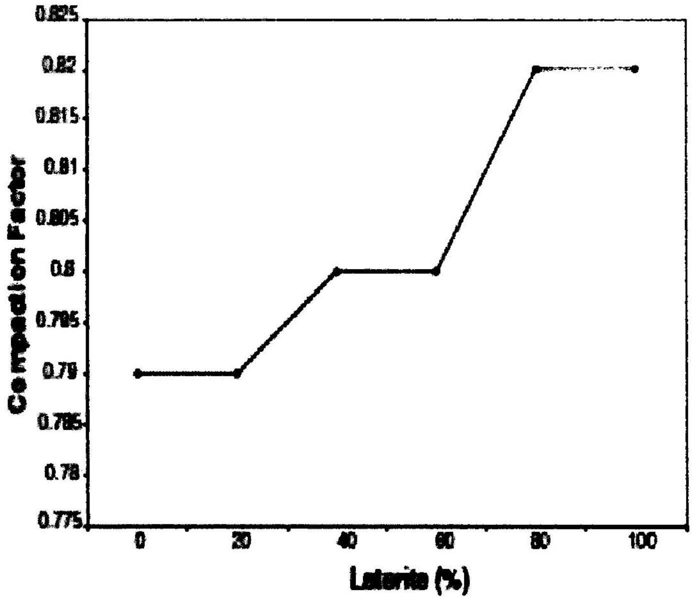


Figure 2.2: Compaction factor of laterised concrete (Udeoyo, et al., 2006)

Osunade (2002) in their study observed that when granite fines are incorporated into laterised concrete enhances its workability. Ryduchowska, (1986) stated that laterite could be utilized as blend with River sand in making concrete. The designed mix used by (Ryduchowska, 1986). Kamaruzaman and Muthasamy (2013) looked at how curing regime affects compressive strength of laterised concrete. They used different variation of laterite aggregate in making concrete with also different curing regime specifically water, natural weather and air. Their results showed that concrete cured in water showed better performance. However, excluding the air cured specimen, other specimens showed rise in compressive strength as the age increases. The outcomes of their study are presented as follows.

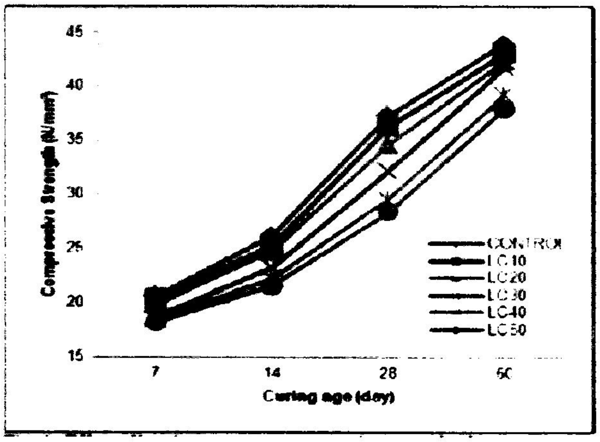


Figure 2.3: Effect of laterite proportion on concrete compressive strength (Muthasamy and Kamaruzaman, 2012)

Ukpata and Ephraim (2012) investigation revealed that the tensile strength of laterised concrete with a blend of quarry dust closely compares favorably with normal concrete. Laterite sand and limestone fillers were utilized by (Saravanan, et al., 2014) in concrete production. The results revealed that 50percent-50percent (Laterite Limestone filler), 75percent-25percent (Laterite-Limestone filler) and control specimen were more or less the equal for grade M20 and M25 concrete.

According to (Osunade, 1994), tensile strength increase with grain size and curing age. In a different study by (Osunade, 2002) granite fines were used as replacement in laterised concrete using three different mix proportions (1:1:2, 1:1.5:3, 1:2:4 and 1:3:6), and observed that the addition of granite reduces tensile strength.

On effect of laterite on flexural strength of laterised concrete, (Osadebe and Nwakonobi, 2007) used two mixed ratios 1:1:2 with a water-cement ratio of 0.65 and 1:2:4with a water-cement ratio of 0.791. They observed that the flexural strength for 1:1:2 was greater than that of 1:2:4 at optimum mix proportion. Udeoyo, et al. (2006)

shows that flexural strength went up with age but falls with upsurge in the laterite proportion. The authors also observed that flexural strength of laterised concrete in comparison to normal concrete is between 58-83percent as presented in Figure 9 .

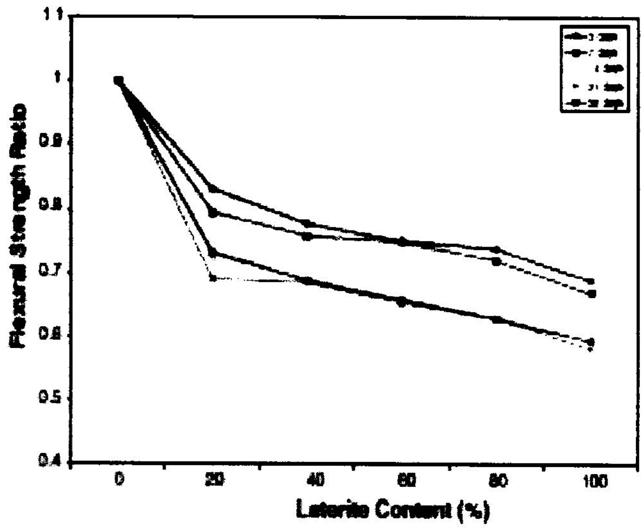


Figure 2.4: Flexural strength ratio of laterised concrete (Udeoyo, et al., 2006)

Ukpata and Ephraim (2012) observed that flexural property of blended laterite and quarry dust closely compares with normal concrete provided laterite content does not exceed 50percent

Ata, et al. (2005) study on the poison's ratio of laterised concrete revealed that the poison's ratio falls between 0.25-0.35 and rises with age at a diminishing rate. The same study also added that methods of curing, compaction and water-cement ratio influences poison's ratio of laterised concrete. Investigation on elastic modulus and deformity modulus of laterised concrete conducted by (Olugbenga, 2007) using three concrete mixes; 1:3:6, 1:2:4 and 1:1.5:3 and water cement ratios; 0.5, 0.6, 0.7, 0.75 showed that there was equal rise in modulus of elasticity and deformity of laterised concrete due to rise in curing age.

Another study was conducted to assess the influence of stress on elastic modulus and modulus of deformity by (Ata and Adesanya, 2007). The same mix ratios was adopted with the former and samples were tested for 7 and 28 days strength. The results of their study showed that an increase in the amount of applied stress resulted in the reduction of modulus of elasticity and deformity.

Although, work have been done on properties of laterised concrete. Nevertheless, very few research looked at its application to structural elements. Olutage, et al., (2013) used five specimen integrating different proportion of laterite soil; 0, 10, 20, 30, and 40percent and reinforcement bars Y10. They observed that laterised concrete gave satisfactory performance compared with normal concrete provided laterite content is less than 25percent.

Another study on concrete beams containing laterite by (Salau and Balogun, 1990) investigated the shear resistance of beams without shear reinforcement. They observed that the mode of failure of those beams does not hinge on laterite proportion but on beam span. They also found that the ultimate cracking load falls with rise in the proportion of laterite. The ultimate shearing was also found to conform to the one specified in CP110. Their results further showed that the ultimate shearing stress rises as the amount of longitudinal reinforcement increased and that the existence of laterite improves the post-crack ability and serviceability conditions of the beams. Figure 10 shows the crack patterns beams.

Laterised concrete have proved to possess good structural properties in contrary to the statement of (Nevile, 1995) saying laterised concrete can hardly produce concrete strength more than 10Mpa. Although, laterite soil was seen to yield less workable concrete. It is important that studies carried out on introducing workability enhancement admixture such as plasticizers or other locally available bio-admixtures (Sathya, et. al., 2013, Abdeljaleel, et. al., 2012). However, it is necessary to understand the long term structural properties of laterised concrete. In addition, more research should be done on structural elements such as beams, columns and slabs of laterised concrete especially on larger specimens in order to fully understand its performance.

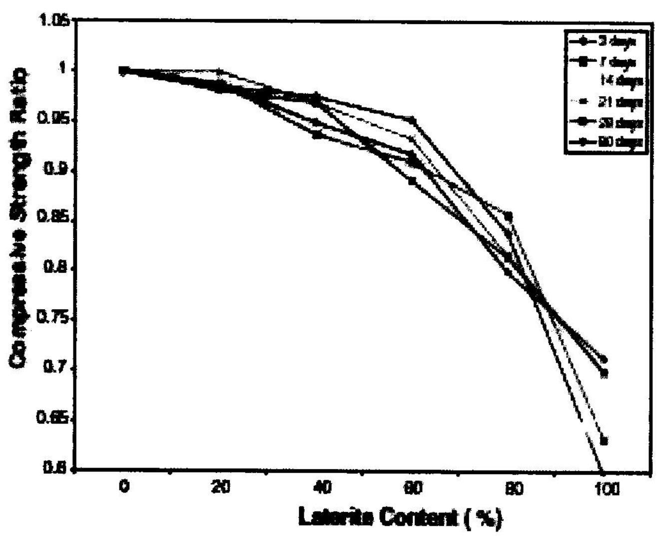


Figure 2.5: Compressive strength of laterised concrete related to the strength of control

The effect of calcined termite mound material (TMM) on the compressive strength of concrete was carried out by Elinwa, A. U. (2006). Setting times test conducted on CTM shows that addition of the material considerably increases the initial and final setting times indicating that the CTM is an accelerator and recommended for cold weather concreting. Its effect on fresh concrete shows that at 40% replacement, the heat of hydration is reduced by 17%. The properties of the hardened concrete indicates that CTM increases the flexural strength more than the tensile strength. The compressive strength decreased as the CTM content increased, while compressive strength of mortar shows gradual increase in compressive strength as curing period proceeded above 60 days. The mortar compressive strength at 10% replacement of cement was above that of the reference mix showing conformity with pozzolanic behaviour.

TMM randomly selected from some habitats of a common tropical specie of termites from Iyeke-Ogba area of Edo state, Nigeria was investigated by Orie, O. U. and Anyata, B. U. (2012). The result of the geotechnical properties of the mound soil showed that mound soil belongs to class SC (Silty Clay) using the Unified Soil Classification System (USCS).A maximum compressive strength of 47.78 N/mm2 with 24mm slump was attained by the addition of 15% TMM, giving 21.83% increase in the compressive strength and 36.92% improvement on workability and concludes that

TMM can be used in construction as an additive in concrete but should not exceed 15%. Oxide composition test result shows the material is a good pozzolana as it exhibits good pozzolanic properties

Ikponmwosa, E., Salau, M. and Mustapha, S. (2011) indicate that the addition of TMM considerably advanced the initial and final setting time of cement base paste and collaborates findings by Elinwa (2006). As the percentage substitution of cement with TMM increases, the initial and final setting time decreased. At 30% substitution level, the initial setting time reduced by 84.6% while the final setting time advanced by 30.19% with these results, it could be opined that TMM is very effective cement setting time accelerator.

According to Claudius K., Duna S. 2006 on the Performance *Evaluation of Calcined Termite Mound (CTM) Concrete with Sikament NN as super plasticizer.* The CTM is proven to be pozzolanic and can be used to replace cement in concrete production but the replacement level should not exceed 10 % replacement by weight of cement. For best results when using CTM the concrete should be cured for more than 28 days.

2.2: Termite Mound

2.2.1 Preliminary tests

The fineness moduli of the soil materials used were calculated as 2.07 for soft sand and 2.00 for termite hill. These values indicate fine aggregates of medium grading. Besides, the coefficients of uniformity were obtained as being approximately equal to 4.00 and 3.00 for soft sand and termite hill soil samples, respectively. The values show that the soil samples are uniformly graded (coefficient of uniformity between 1.0 and 5.0). Poorly graded soils (coefficient of uniformity less than 1.0) are unsuitable for plastering purposes. The as-used moisture contents of the common sand and the termite hill were obtained as 0.76% and 5.17%, respectively. Since termite hill is a cohesive soil, the Atterberg's limits were determined. The tests indicated values of 25%, 10%, 15% and 1.32 for the liquid limit, the plastic limit, the plasticity index and the liquid index, respectively. These values indicate that the termite hill is medium cohesive with its range of plasticity index between 10 and 20%.

2.2.2 Compressive strength

The compressive strength variations with curing age at various levels of percentage replacement of cement with termite hill and lime for both mix ratios are shown in Fig below. Test results showed that the compressive strength of the mortar cubes increases with age and decreases with increasing percentage replacement of cement with lime and termite hill. However, for mix ratio 1:6, up to 20% replacement of cement with either lime or termite hill, all the mortar cubes had roughly the same 28-day strength, though the cement/termite hill mixture had higher early (7-day) compressive strength at these replacement levels. Subsequently, the cement/ termite hill mortar cubes exhibited a higher compressive strength. For mix ratio 1:4, mortar cubes made from cement/lime and cement/termite hill mixtures had almost the same strength only at 50% replacement level. At replacement levels less than 50%, the cement/termite hill mixtures exhibited greater strength. Generally, it was observed that mortar cubes made from cement.

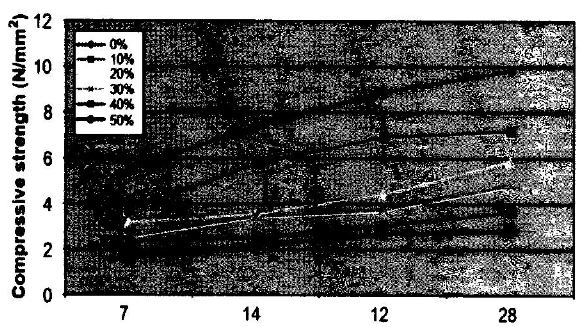


Fig. 2.6. Compressive strength vs. curing ages of cement + termite mound (mix 1:6)

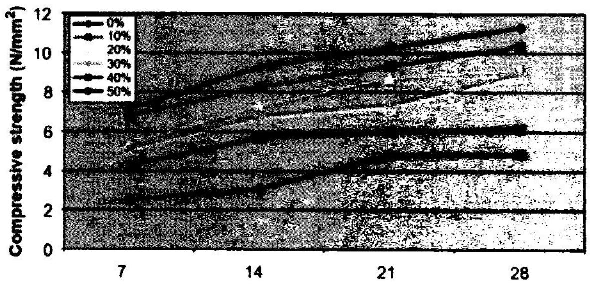


Fig. 2.7. Compressive strength vs. curing ages of cement + termite (1:4)

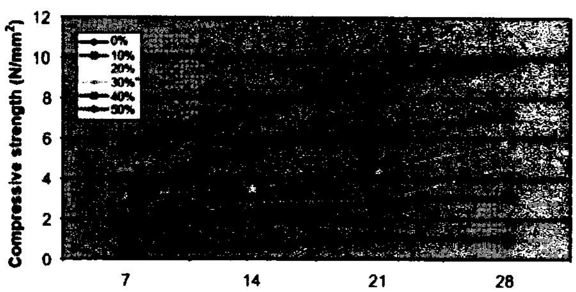


Fig. 2.8. Compressive strength vs. curing ages of cement + Lime (Mix 1:6)

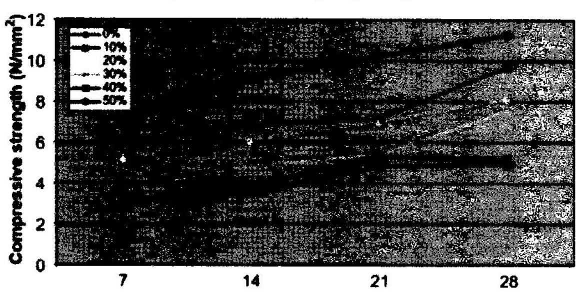


Fig. 2.9. Compressive strength vs. curing ages of cement + lime (1:4)

Termite hill mixtures exhibited greater compressive strength than those made from cement/lime mixtures. At zero replacement level, the 28-day mortar cube compressive strengths for specimens made from mix ratios 1:6 and 1:4 are 9.80N/mm^2 and 11.26N/mm^2, respectively. Both mixes exhibited good compressive strength (5.85N/mm^2) up to 20% replacement for mix ratio 1:6. For mix ratio 1:4, the cement/lime mixtue had good compressive strength (7.72N/mm^2) up to 30 %

replacement level while the cement/termite hill mixture had good compressive strength up to 40% replacement level ($8.84N/mm^2$ at 30% replacement level and $6.12N/mm^2$ at 40% replacement level). For all the replacement levels considered, the coefficients of variation of test results range between 1.20% and 2.13%.

These values could be considered excellent from an engineering standpoint.

2.2.3 Water absorption

The figure below shows the rate at which the mortar cubes absorb water within 24h of casting. As the percentage replacement of cement increases, the quantity of water absorbed increases. Generally, water absorption was higher in mixtures containing lime (18.10% and 14.20 % for mix ratios 1:6 and 1:4, respectively, both at 50 % replacement level) than those containing termite hill (16.10% and 13.02% for mix ratios 1:6 and 1: 4, respectively, both at 50% replacement level). At 0 % replacement level, the percentage of water absorbed was 11.11% for mix ratio 1:6 and 7.63% for mix ratio 1:4. The percentages of water absorbed at 20% replacement level for mix ratio 1:6 were 13.39% and 14.80% for cement/termite hill and cement/lime mixtures, respectively.

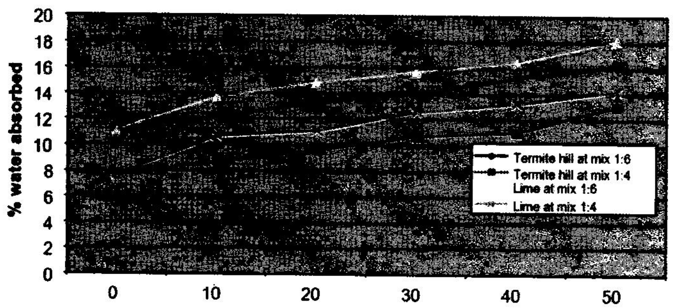


Fig. 2.10. Water absorbed vs. % replacement of 1:4 and 1:6 mix

At 30% replacement level, up to which the mortar cubes made from mix ratio 1:4 showed good compressive strength, the percentages of water absorbed were found to be

10.66% and 12.55% for cement/ termite hill and cement/lime mixtures, respectively. These values are still comparable with the values obtained for normal mortar mixtures using only cement as binder. For all the replacement levels considered, the coefficients of variation of test results range between 1.38% and 2.41%. These values are low and could be considered reasonable from an engineering standpoint.

The chemical composition of the termite mound sample used had silica (SiO_2) content of 70.78%; a combined percentage of silica (SiO_2) and Alumina (Al_2O_3) of more than 70%, a requirement of which a good binder should meet (Syagga *et. al* 2001; Pekmezei and Akyuz, 2004 and Justness *et. al.*, 2005). The composition also meets the requirements of ASTM C 618 (2008) for a combined percentage content of SiO_2, Al_2O_3 and Fe_2O_3 of more than 70% as stipulated. Thus, termite mound can be considered a suitable material for use as a binder. The physical properties as presented in Table 2 indicates a moisture content of 2.20%; a liquid and plastic limits of 36% and 17.58%, respectively and a corresponding plasticity index of 18.42%. The plasticity index which is greater than 17 is an indication that the termite mound is a highly plastic soil (Murthy, 2007).

Table 2.3 : physical properties of Termite Mound and fine aggregates

Properties	Termite mound	sand
Specific gravity	2.57	2.65
Coefficient of uniformity	3.0	4.37
Moisture content (%)	2.20	0.74
Fineness modulus	2.09	2.13
Liquid limit (%)	36.0	
Plastic limit (%)	17.58	
Plasticity index (%)	18.42	

Termite mound-lime content. It was equally observed that in all the mixes, the mix ratio 1: 4 had a higher compressive strength than mixes in the mix ratio 1: 6. At 28 days hydration period, which is the standard age, the compressive strength for mix ratio 1: 4 were 16.4 N/mm^2, 11.7 N/mm^2, 10.80 N/mm^2, 9.80 N/mm^2, 6.60 N/mm^2, and 5.40 N/mm^2 for replacement level of 0%, 10%, 20%, 30%, 40% and 50%, respectively; while that of mix ratio 1: 6 were 11.60 N/mm^2, 10.4 N/mm^2, 6.40 N/mm^2, 6.40 N/mm^2, 5.60 N/mm^2 and 5.40 N/mm^2 for 0% to 50% termite mound-lime content, respectively.

From these results it can be said that mixtures containing 0% and 10% termite mound lime content of mix ratio 1: 4 met the requirement for type S mortar as specified by ASTM C270 (2006) while other mixtures from both mix ratios could be classified into type N mortar for having attained a value above the minimum of 5.2N/mm^2 (ASTM C270; 2006). Therefore, the blending of cement with termite mound-lime up to 50%

produced a general all-purpose mortar with higher flexural bond strength (Type S) and good bonding capabilities and workability (Type N).

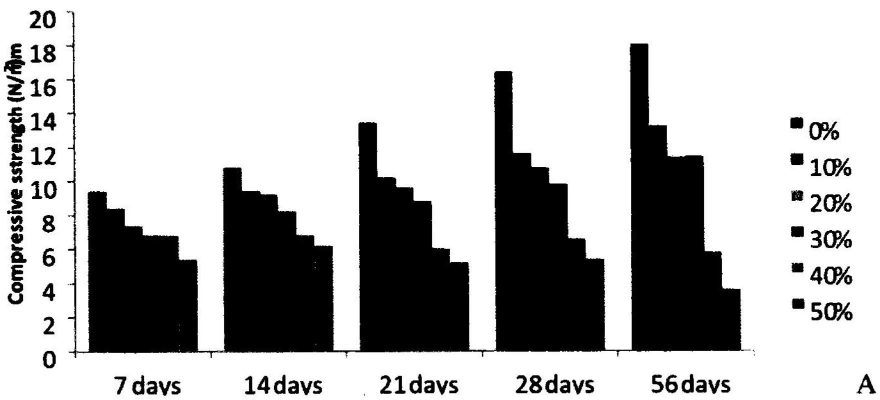


Figure 2.11: Variation of compressive strength against curing age for Termite mound-lime

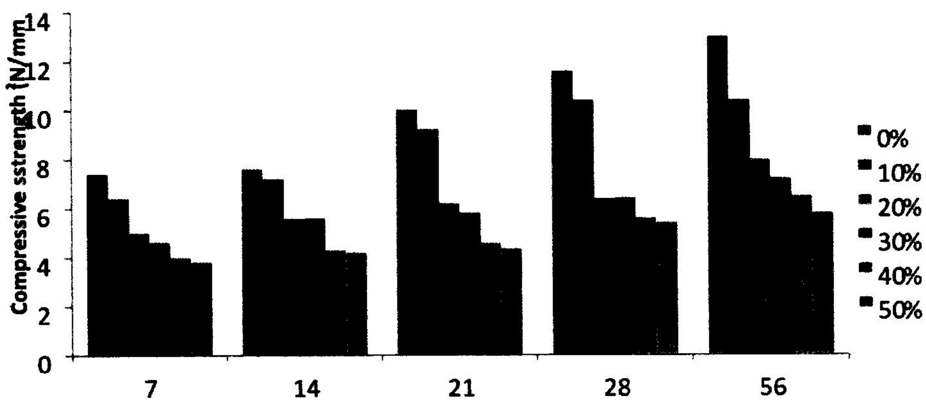


Figure 2.12: Variation of compressive strength against curing age for termite mound-lime (1:6 mix)

2.2.4 Compressive Strength of Termite Mound – Lime Cement Mortar in Acidic Environment

The compressive strength of termite mound-lime cement blended mortar specimens of 1: 4 and 1: 6 mix ratios exposed to Sulphuric and Nitric acids of 1% and 3% concentrations, in each acid type, are presented in Tables 2 and 3. The compressive strength is observed to reduce with increased in curing age, replacement level of cement with termite mound-lime from 0% to 50% as well as acid and concentration in each mix ratio. However, it is equally observed that a mix ratio of 1: 4 seems to be less effected by the acid attack than a mix ratio of 1: 6. For instance, the compressive strength attainment at 28 days in mix ratio 1: 4 and immersed in H_2SO_4 of 1% concentration reduces from 5.20N/mm^2 for the control to 1.04N/mm^2 for 50% termite mound-lime content; and that a concentration of 3% were much affected than 1% concentration, which is an indication that the higher the concentration of the solution the grater the effect of the attack. Nitric acid was observed to have less effect on the specimens when compared to Sulphuric acid.

It is worthy to note that the Ternary blended mortar made with termite mound-lime cement has less resistance to acid attack than the control. The reason could be that the termite mound is not an amorphous pozzolan, since it was not calcined (Sabir *et al.*, 2001), and therefore could not consume the calcium hydroxide [Ca $(OH)_2$] released during the hydration process of the cement, and became vulnerable to the acid attack. Therefore, the termite mound is not recommended for use without being calcined to make it amorphous before being used in acidic environment.

The percentage loss in compressive strength for specimens immersed in 1% H_2SO_4 solution range between 34.04% and 80.74% for mixtures of mix ratio 1: 4 (Figure 3), and 24.59% and 93.10% for mixtures of mix ratio 1: 6 (Figure 4). In 3% H_2SO_4 solution, the percentage loss increased to 37.02% and 92.59% for mixtures in the ratio of 1: 4 ratio (Figure 5), and 27.03% and 94.83% for mixtures of 1: 6 ratio (Figure 6).

The high increase in the percentage loss in strength due to the H_2SO_4 attack confirmed the earlier findings by Neville (2000) that Sulphuric acid is very damaging to cement matrix as it combine an acid and Sulphate attack.

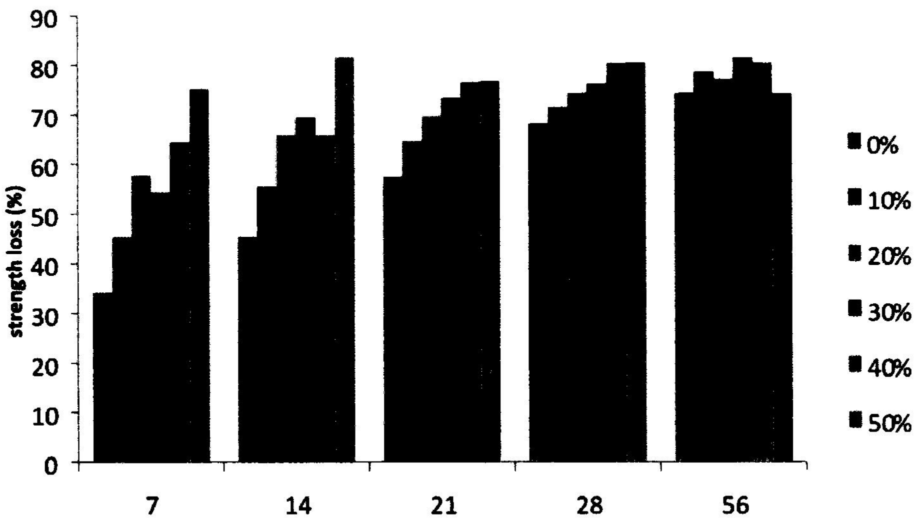


Figure 2.13: Variation of compressive strength loss against curing age for termite (1:4 mix) in H2SO4

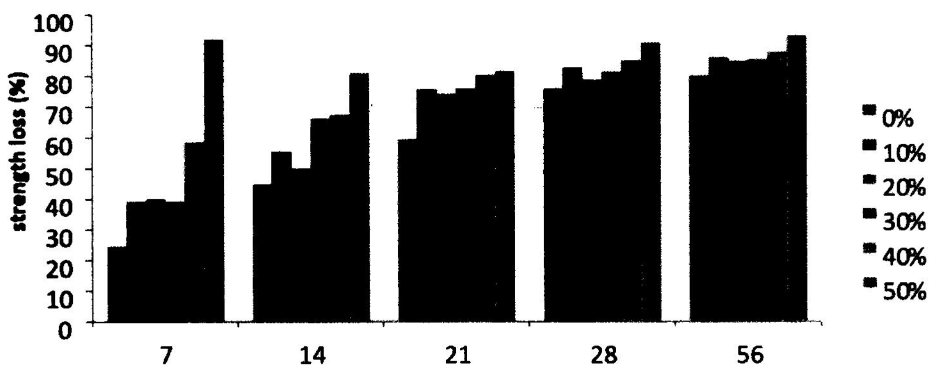


Figure 2.14: Variation of compressive strength loss against curing age for termite mound lime blended cement Mortar mix ratio 1:6

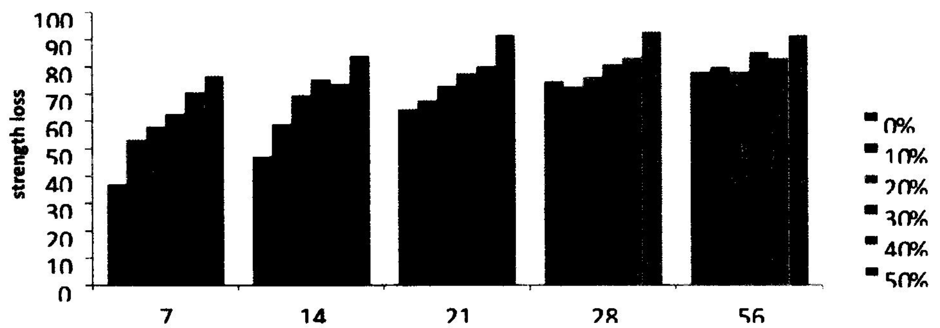


Figure 2.15: Variation of compressive strength loss against curing age for Termite mound lime Blended Cement Mortar mix ratio 1:4 exposed in 3 % H_2SO_4 concentration.

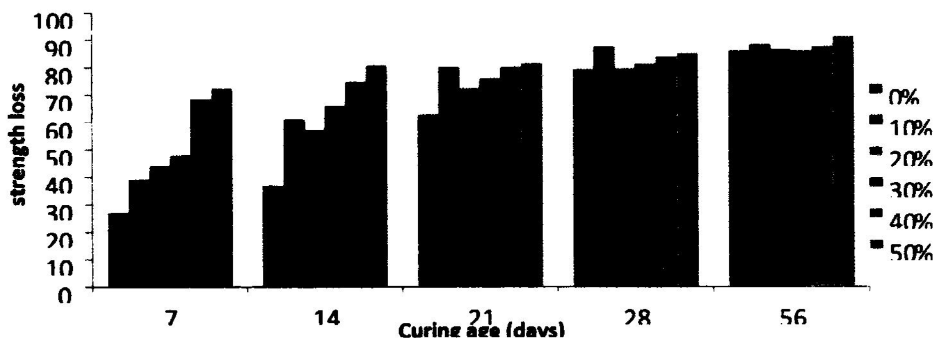


Figure 2.16: Variation of compressive strength loss against curing age for Termite mound lime. Blended Cement Mortar mix ratio 1:6 exposed in 3 % H_2SO_4 concentration

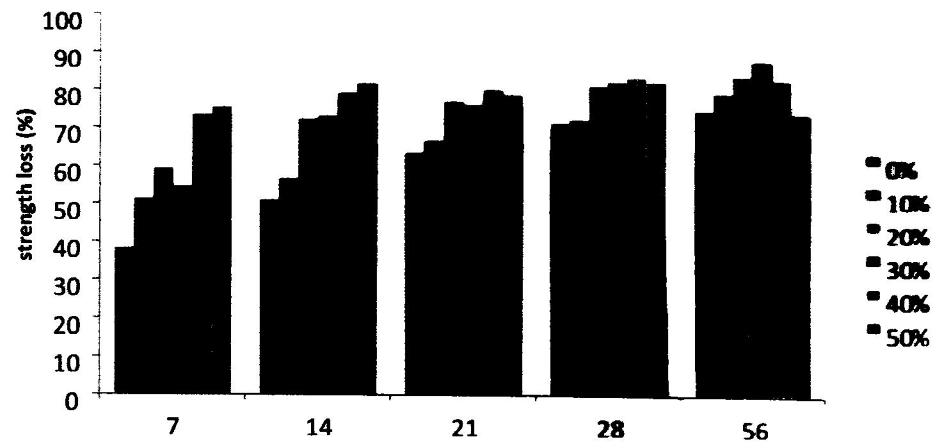


Figure 2.17: Variation of compressive strength loss against curing age for Termite mound-Lime Blended Cement Mortar mix ratio 1:4 exposed in 1 % HNO_3 concentration.

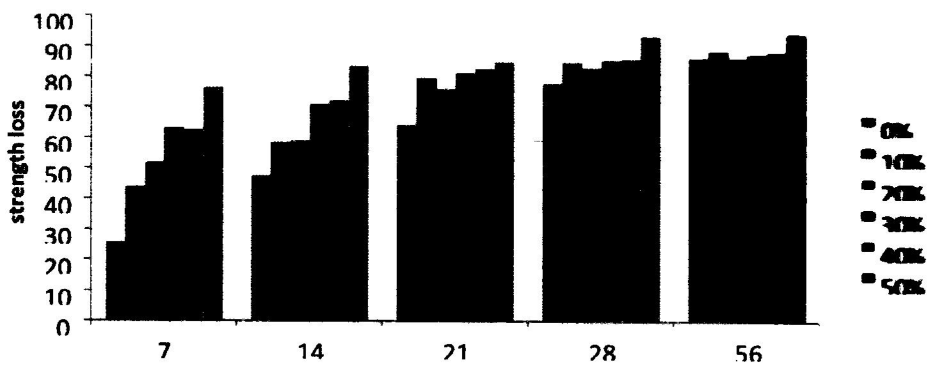


Figure 2.18: Variation of compressive strength loss against curing age for Termite mound-lime Blended Cement Mortar mix ratio 1:6 exposed in 1 % HNO_3 concentration.

CHAPTER THREE

3.0 MATERIALS AND METHODOLOGY

The mix proportion for the production of concrete was having a mix proportion of 1:2:4 and water-cement ratio of 0.5. PTM was used to replace fine aggregates by weight in the range 10,20,30,40 and 50 %. Results for moisture content and absorption, grain analysis, slump and compressive strengths were recorded.

3.1 Theoretical Background

Termite mounds are bioengineered granular ensembles that remain stable over decades, a vital requirement for termite societies that house millions of individual termites. An experimental study on the mechanobiology of mounds and mound soil of the fungusgrowing termite Odontotermes obesus (Rambur) demonstrated that termites are capable engineers. Mound soil was significantly different in its physical and mechanical properties compared to the surrounding or 'control' soil. However, mound and control soils did not differ in clay mineralogy. Utilizing the finer soil fraction, termites altered the soil significantly by cohering grains through their secretions into units called boluses, in the presence of water. Termites modulated the amount of water close to the plastic limit of the soil while preparing these boluses such that the soil could be effectively moulded. The cementation effected by termites using their secretions and/or excretions enhanced the strength of the soil tenfold, which may not be achievable otherwise. The soil modification achieved by the termites decreased mound susceptibility to erosion and collapse. Termites successfully cemented foreign materials, suggesting a wide range of cementation abilities. Slope stability analysis with intact mound soil revealed a significant increase in the safety factor of the mound compared to that of reconstituted soils

3.2 Cement

Portland cement is the most common type of cement in general usage. It consists of a mixture of oxides of calcium, silicon and aluminum. Portland cement and similar materials are made by heating limestone with clay, and grinding this product (called clinker) with gypsum (Concrete Wikipedia, 2009).

Termite mound material and lime has been used as partial replacement of cement in plastering and results showed that the compressive strength of the mortar cubes increases with age and decreases with increasing percentage replacement of cement with lime and termite hill (Olusola et al. 2006).

3.3 Fine Aggregates

Fine aggregates, consisting of sand, and crushed stone make up the bulk of a concrete mixture. Recycled aggregates may be used as partial replacements of natural aggregates, while a number of manufactured aggregates, including air-cooled blast furnace slag and bottom ash are. also permitted. Decorative stones such as quartzite, small river stones or crushed glass are sometimes added to the surface of concrete for a decorative finish (Concrete Wikipedia, 2009).

3.4 Coarse Aggregates

A coarse aggregates are aggregates that is retained on the 4.75mm sieve.They are particulate material used in construction including sand, gravel, crushed slag, recycled concrete and geosynthetic aggregates.

3.5 Termite Mold

Termites are major detritivores, particularly in the subtropical and tropical regions, and their recycling of wood and other plant matter is of considerable ecological importance (Termite Wikipedia, *2(09).* As eusocial insects, termites live in colonies that, at maturity, number from several hundred to several million individuals.

3.5.1 Extraction of Termite Mound Material

The termite mounds that were chosen were the ones that have not been subjected to human interference chemically since the chemical properties of the termite mound are important. The material from the selected termite mound were extracted by breaking them open with a pick axe and shovel. Depending on the size of the termite mound, all or part of the mound were broken and transported to the laboratory for analysis and experiments. Mound materials were collected based on three different specifications and stored separately:

a. Hardened parts of the mound that were dry.
b. Hardened parts that form that inner walls of the mound, and
c. Freshly constructed moist parts.

During extraction and transportation of the termite mound materials, contamination of the material by way of insect control during breaking of the termite mound or the use of unclean containers while transporting the material, were avoided. The extracted termite mound materials were stored away from dust and interference by addition of other materials to it. The material from the outer parts of the mound were allowed to air dry for four weeks after which they were broken down into finer, sand-size particles which were to be analyzed and used in the preparation of concrete. The moist, freshly built material and the hardened parts from the inner walls of the termite mound were temporarily stored in a sealed polythene bag in order to prevent it from drying out before chemical analysis.

3.5.2 Location of Termite Mounds

Termite mounds within Federal University Oye-Ekiti, Ikole Campus, Faculty of Engineering were located and suitable ones were selected from which mound material was extracted. The location of the termite mound as well as the physical conditions around them were recorded. The physical conditions were nearness to man-made structures, type of surrounding vegetation (whether cultivated or otherwise), and proximity to natural sources of water.

3. 6 Water

Combining water with a cementitious material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it, and allows it to flow more easily. Less water in the cement paste will yield a stronger, more durable concrete; more water will give an easier-flowing concrete with a higher slump. Impure water used to make concrete can cause problems when setting or in causing premature failure of the structure. Hydration involves many different reactions, often occurring at the same time (Concrete Wikipedia, 2009).

3.7 Materials Estimation and Calculation of Mix Proportion

The materials to be used such as cement, fine aggregates which entails both the sand and the termite mound, the coarse aggregates and Water using established formulas and principles.

On each day casting, 3×6 = 18 cubes

While the total cubes to be casted for the compressive strength test is 18×6 = 96 cubes.

1 cubes = $0.0034m^3$

Mix Ratio = 1:2:4

Water cement ratio = 0.5

Assuming r_{cm} =$2400kg/m^3$

Density, $r = \frac{m}{v}$

I cubes mass = 2400×0.0034 = 8.1kg

96 cubes = 8.1 ×96 = 777.6kg, approximately 780kg

Cement = $\frac{1}{7} \times 780 = 112kg$

Sand = $\frac{2}{7} \times 780 = 224kg$

Granite = $\frac{4}{7} \times 780 = 448kg$

Furthermore, the volume of cylinder have to be calculated, hence using the formula $\pi r^2 h$, where r = 150mm and h= 300mm.

Table 3.1: The Mix Proportion (Kg/M³) For the Compressive Test

Mix designation	Binder	Fine aggregates		Coarse Aggregates	Water
	Cement	sand	Termite mound	granite	
M_0	20.8	41.70	0.00	83.30	10.40
M_1	20.8	37.58	4.17	83.30	10.40
M_2	20.8	33.36	8.34	83.30	10.40
M_3	20.8	29.19	12.51	83.30	10.40
M_4	20.8	25.02	16.68	83.30	10.40
M_5	20.8	20.85	20.85	83.30	10.40

Hence the mix design for 28 and 90 days is different from that of 7, 14 and 60 days because the former is a combination of both cylindrical cubes and square cubes.

Table 3.3 Mix Design for 7, 14 And 60 Days (Compressive Test Cubes Only)

Mix designation	binder	Fine aggregates		Coarse Aggregates	water
	cement	sand	Termite mound	granite	
0	3.50	7.00	0.00	14.00	1.75
10	3.50	6.30	0.70	14.00	1.75
20	3.50	5.60	1.40	14.00	1.75
30	3.50	4.90	2.10	14.00	1.75
40	3.50	4.20	2.80	14.00	1.75
50	3.50	3.50	3.50	14.00	1.75

3.8 Production of Concrete

Concrete was mixed in the ratio 1:2:4 by weight. One measure of cement to two measure of fine aggregates (sand) to four parts of coarse aggregates (granite). The fine aggregates were varied and it was replaced at an interval of 10% up to 50%. The soil from the termite mound was sieved with a 300μm sieve before being used in the preparation of concrete to remove the silt and clay sized particles. Ninety 150×150×150mm concrete cubes were made with each of the composition using the wooden forms. The forms were lubricated internally in order to allow easy removal of the cubes after they have set. Each cube was labelled and a record sheet showing the composition, date of preparation, and date of crushing the cubes for each cube was prepared. The cubes were removed from the forms the day after casting and were cured while submerged in the bath containing water for 7, 14,21, and 28 days. Three 100 x 100 x 100mm cubes composing of 50% termite mound material and 50% cement by volume were prepared and cured for 28 days before crushing. The termite mound soil was sieved with the 300J.1msieve to eliminate silt and clay sized particles.

Three 100 x 100 x 100mm cubes composing only of termite mound soil were also prepared and crushed after 28 days without curing in water. The cubes were kept under normal atmospheric conditions. The termite mound soil used in this case was not sieved with the 300μm sieve.

3.9 Experimental Investigations

3.9.1 Preliminary Investigations (Analysis of Termite Mound Material)

Mechanical, physical and chemical analysis were conducted on the materials extracted from the termite mound to ascertain the condition the properties relevant to concrete technology as well as general soil properties relevant to civil engineering.

1. SPECIFIC GRAVITY:

Objective: To determines the specific gravity of cement using Le-Chatelier Flask.

Apparatus: Le-Chatelier Flask, Digital weighing balance

Material required: sand, PTM, Kerosene

Theory: The specific gravity of a PTM is not a property normally determine for its own sake, but it is required in the measurement of its specific surface. The specific gravity is defined as the ratio between the weight of a given volume of PTM and weight of an equal volume of water. The test for finding the specific gravity of pulverized termite mound was originally considered to be of much importance in view of the fact that other tests lead to more definite conclusions. The most popular method of determining the specific gravity of PTM is by the use of a liquid such as water free kerosene. Which does not react with PTM.

A specific gravity bottle or a standard Le-chatelier flask may be used.

Procedure :

- Weight of specific gravity bottle dry, W_1
- The bottle is filled with distilled water and the bottle is weighted W_2
- The specific gravity bottle is dried and it is filled kerosene and weighted W_3
- Pour some of the kerosene out and introduce a weighted quantity of PTM into the bottle.
- Roll the bottle gently in the inclined position until no further air bubble rise to the surface.

The bottle is filled to the top with kerosene and it is weighted W_4.

PLATE 3.1: experiment on specific gravity

Observation :

Weight of empty dry bottle (w1) = gms

Weight of bottle + water (W2) = gms

Weight of bottle + kerosene (W3) = gms

Weight of bottle + PTM + kerosene (W4) = gms

Weight of PTM (W5) = gms

Specific gravity of kerosene $g= \frac{W_3-W_1}{W_2-W_1}$

Specific gravity of PTM $G= \frac{W_5(W_3-W_1)}{(W_5+W_3-W_4)(W_2-W_1)}$

2. ***MECHANICAL SIEVE ANALYSIS***: The particle size distribution was determined for the broken material from the termite mound.

Objective: To determine fineness modulus of fine aggregates (PTM)

Apparatus: Set of IS standard sieves, Digital weighing balance, Sieve shaker, Tray, riffle box, etc.

Material required: Sand, pulverized Termite mound

Theory: The aggregate most of which passes IS 4.75 mm sieve is classified as fine aggregates. The fine aggregates obtained from natural disintegration of rocks and deposited by streams are knows as natural sands. Fine aggregates resulting from crushing of hard stone and natural gravel are known as crushing stone sand and crushing gravel sand respectively.

Aggregate most of which is retained on IS 4.75 mm sieve is known as coarse aggregate. It may be in the form of uncrushed gravel or stone resulting from natural disintegration of rocks.

Procedure:

1 kg of PTM was taken from a sample of about 50 kg by quartering or through riffle box.

The relevant sieves were arranged one above the other with the sieve size increasing from the top. The pan was put at the bottom. The sample was placed in the top sieve and covered.

The set of sieves were shaken for 10 to 15 minutes in a sieve shaker.

The amount of aggregate retained on each sieve was weighed along with the pan.

Plates 3.2: grain grading Analysis

3. ***MOISTURE CONTENT***: This is used to determine the amount of water in a material and it is recorded in percentage.

PROCEDURE: Portions of the previously sealed soil from the inner walls of the termite mound were placed in labeled crucibles of known and recorded masses.

- The crucibles were weighed with the soil in them and then placed in an oven set at 140°C for 24 hours.
- The crucibles with their contents were weighed after removal from the oven. The mass of the dry soil in the crucible was determined and hence the mass of water contained in the soil at the initial state.
- The moisture content is the ratio of the mass of water in the soil to the mass of the dried 'soil expressed as a percentage.

Plates 3.3: moisture content experiment using termite mound

4. **CHEMICAL ANALYSIS**: The soil from the termite mound was taken to a chemical laboratory for chemical analysis to determine the PH, carbon, Nitrogen, Phosphorus, Sodium, potassium, Calcium, and Magnesium contents, and the exchangeable acids of the soil. The freshly built, moist termite mound part was weighed and an identical mass of distilled water was added to it. The mixture was thoroughly mixed and allowed to stand for 24 hours. The mixture was then filtered using No. 1 filter paper and the filtrate was taken to the chemical laboratory for the analysis of the chemical contents.

PROCEDURES

SAMPLE DIGESTION

One gram of pulverized sample was weighed into a conical flask and moistened with distilled water.100ml aqua regia was added to it and boiled steadily to almost dryness.

The sample was then cooled and and leached with 5ml of 6M H_2SO_4.5ml of distilled water was added and boiled for 10 minutes. The Sample was then cooled and filtered. The filtrate was made up to 100ml and presented for mineral analysis.

MINERAL ANALYSIS

The mineral content of the digested sample were analyzed using Atomic Absorption Spectrophotometer (Buck Scientific 210 VGP), Flame photometer (FP 902 PG) and their oxides were calculated using a conversion table.

SULFITE DETERMINATION

One gram of the sample is measured accurately and transferred into a flask with a ground glass stopper, containing 50 ml of 0.05 mol/l iodine solution exactly measured, and dissolved. It was allowed to stand for 5 minutes, and 2 ml of diluted hydrochloric acid was added. Then, the excess iodine was titrated with 0.1 mol/l sodium thiosulfate solution (indicator: starch TS).

LOSS ON IGNITION

Loss on ignition is determined using the standard method (ASTM D7348). Samples are placed in weighed crucible and weighed .weight loss is measured after heating the samples overnight at 100°C to remove water, at 550°C for four hours to remove organic matter, and at 1000°C for two hours to remove carbonates. After each heating step, the firebrick holding crucibles is allowed to cool completely in the oven or furnace before weighing, or placed in a dedicator if crucibles cannot be weighed immediately. The weight loss of the sample due to heating is then determined, the constant weight obtained is then measured as loss on ignition. (ASTM D7348)

3.9.2 Main Investigation

1. ***Workability***: Consistency (Slump) Test Procedure

Equipment needed: Slump cone in clean and good condition

Smooth, rounded 16.0 mm (5/8 in.) diameter steel rod with a rounded tip

Consistency (Slump) Test Procedure:

- Obtain a representative concrete sample. Start test within 5 minutes of when sample was taken.
- Dampen the slump cone and place on a flat, moist, non-absorbent and rigid surface; hold the cone firmly in place by standing on the foot pieces.
- Immediately fill the cone in 3 layers, each layer approximately one-third the volume of the mold or about 67 mm (2 5/8 in.) for the first layer and 155 mm (6 1/8 in.) for the middle layer.
- Rod each layer with 25 strokes of the tamping rod. Uniformly distribute the strokes over the cross-sections of each layer making approximately half of the strokes near the perimeter, then progress with vertical strokes spirally toward the center, slightly penetrating into the underlying layer. In rodding the top layer, an excess of concrete is maintained above the top of the cone. After the top layer is rodded, the surface of the concrete is struck off even with the top of the cone.

- Remove any excess spillage of concrete from around the base of the cone and lift the cone clear of the concrete allowing the concrete to settle or slump under its own weight. Slowly lift the cone vertically and carefully to secure a proper result, with the lifting operation taking approximately 3 to 7 seconds.
- The amount of slump is measured immediately after the mold is lifted by placing the rodding bar across the inverted mold and measuring from the top of the mold to the displaced original center of the top of the concrete. Record the slump as measured to the nearest 5 mm (1/4 in.).

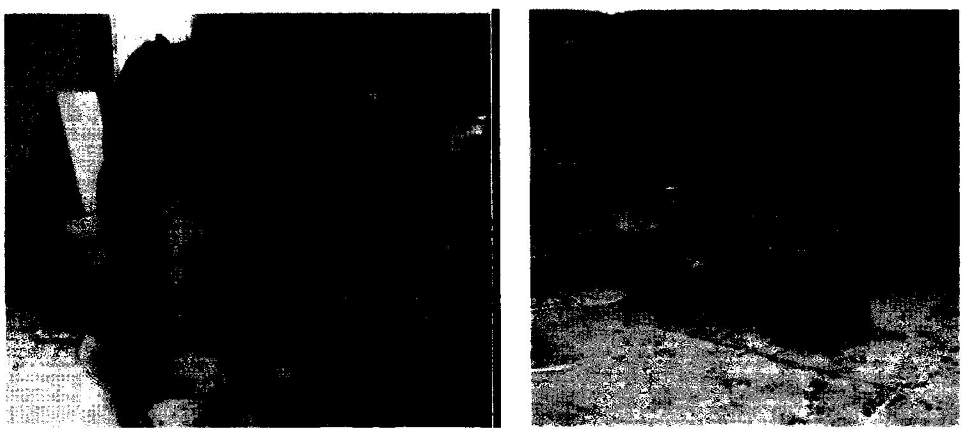


PLATE 3.4: Determination of concrete workability (slump test)

2. Compressive and Tensile Test:

Objective: To determine the compressive and tensile strength of concrete with PTM

Apparatus: Cube moulds- Moulds for the cube specimens of $50cm^2$ face area, shall be metal not amenable to attacked by cement mortar, and there shall be sufficient material in the sides of the moulds to prevent spreading and warping. The moulds shall be rigidly constructed in such a manner as to facilitate the removal of the moulded specimen without damage. The moulds shall be machined so that when assembled, the dimensions and the internal faces shall be accurate to the following limits. Also a cylindrical mould of dimension 150mm × 300mm for the tensile test.

- Poking rod.
- Digital weighing balance
- Measuring flask
- Compression testing machine

Material required: Cement, sand, gravel, PTM, water

Procedure:

Mix Proportions and mixing

Clean appliances shall be used for mixing. The temperature of water and that of the test room shall be 27 +_2 ^{0}C

Place on nonporous plate a mixture of cement: standard sand: Gravel in the proportion of 1:2:4 by weight. Mix it dry with towel for one minute and then with water until the mixture is of uniform colour. The time of mixing shall in any event be not less than 3 minutes and should the time taken to obtain a uniform colour exceed 4 minutes the mixture shall be rejected and operation shall be repeated with a fresh quantity of cement, sand and water.

Moulding Specimens

In assembling the moulds ready for use, cover the joints between the halves of the mould with a thin film of petroleum jelly and apply similar coating of petroleum jelly between the contact surfaces of the bottom of mould and its base plate in order to ensure that no water escapes during vibration. Treat the interior faces of the mould with a thin coating of mould oil.

The mortar shall be prodded 20 times in about 8 seconds to ensure elimination of entrained air and honey combing. Place the remaining quantity of mortar in the hopper of the cube mould and prod again as specified for the first layer and then compact the mortar by vibration. The period of vibration shall be two minutes at the specified speed 12000+_400 vibrations per minute. At the end of the vibration remove the mould together with the base plate from the machine and finish the top surface of the cube in the mould by smoothing the surfaces with the blade or a trowel.

PLATE 3.5: casting of cubes

Curing

Keep the filled mould at a temperature of 27+2`c in an atmosphere of at least 90% relative humidity for 24 hours after completion of vibration. At the end of that period remove them from mould and immediately submerged in clean fresh water and keep there until taken out just prior to breaking. The water in which the cubes are submerged shall be renewed every 7 days and shall be maintained at temperature of 27+_2`c. after they have been taken out and until they are broken the cubes shall not be allowed to become dry.

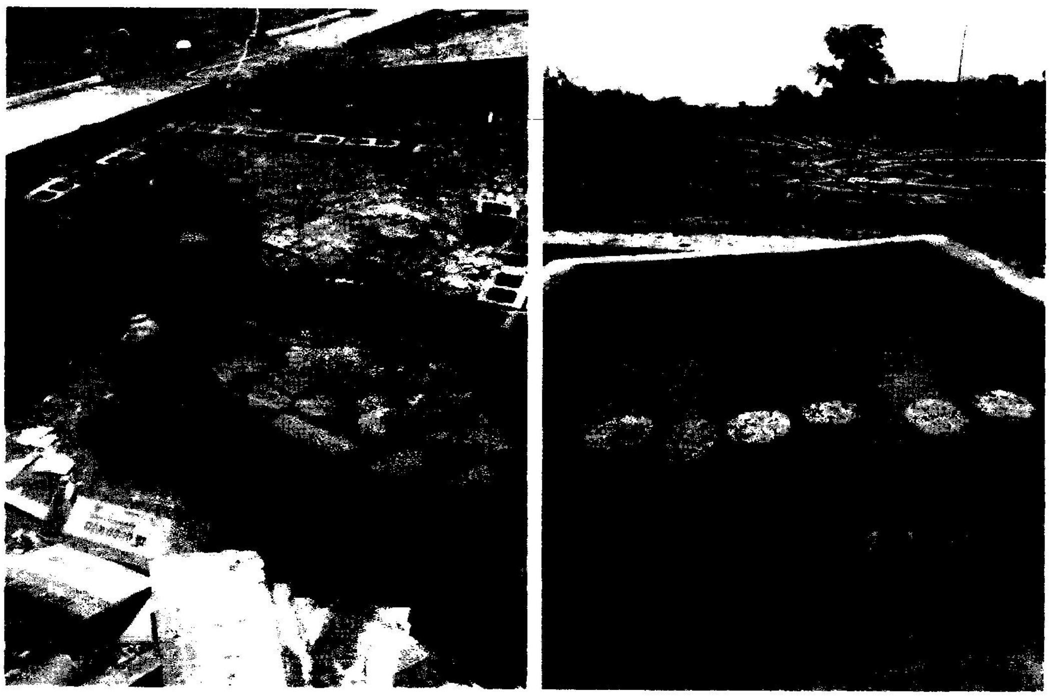


Plate 3.6: curing of cubes

Testing

Test the three cubes for compressive strength at the periods mentioned below, the periods being reckoned from the completion of vibration. The cubes shall be tested on their without any packing between the cube and the steel plates of the machine. One of the platens shall be carried on a base and shall be self-adjusting and the load shall be steadily and uniformly applied, starting from zero at the rate of 350 kg/cm^2/minute.

CHAPTER FOUR

4.0 RESULTS AND ANALYSIS

Preliminary investigations

4.1.1 Physical Investigations

In order to characterize the properties of the aggregates used, some preliminary investigations were carried out on the fine aggregates. Some of the test carried out included: density, specific gravity, water absorption, Mechanical Analysis and chemical composition. All these were carried out in accordance to relevant standards. The results of the physical properties are shown in Table 4.1

TABLE 4.1: Physical Properties

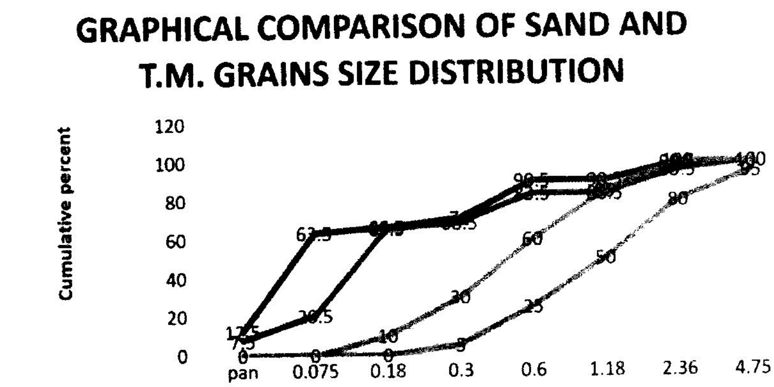
Properties	Termite mound	Sand
Specific gravity	2.19	2.50
Moisture content	9%	6%
Density	1639kg/m3	2043Kg/M3
Water Absorption	29%	17%
Fineness modulus	0.85	0.7

From the table above, it can be observed that the values obtained for weight-based parameters like: bulk density and specific gravity, for fine aggregates were higher than the values obtained for PTM. These results were in agreement with values obtained by Udoeyo (2006) and Ukpata, J.O (2012). Also, the values for water Absorption obtained for PTM is more than that of fine aggregates. This suggest that PTM is more porous than the fine aggregates used.

4.1.2 The Particle Size Analysis for the Sand and PTM

Table 4.2: Grain Analysis of sand And PTM

Sieve size (mm)	**Cumulative % retained R_n**		100 – R_n		**Fine aggregates Grading Limits % Passing (by Mass)**	
	TM	sand	Tm	Sand	minimum	Maximum
4.75	7.5	12.5	92.5	87.5	95	100
2.36	20.5	63.5	79.5	36.5	80	100
1.18	65.5	66.5	34.5	33.5	50	85
0.60	68.5	71.0	31.5	29.0	25	60
0.30	83.5	90.5	16.5	9.50	5	30
0.18	83.5	0.00	16.5	9.50	0	10
0.075	95.5	99.5	4.50	0.50		
Pan	100	100	0.00	0.00		



	pan	0.075	0.18	0.3	0.6	1.18	2.36	4.75
TERMITE MOUND	7.5	20.5	65.5	68.5	83.5	83.5	95.5	100
SAND	12.5	63.5	66.5	71	90.5	90.5	99.5	100
Minimum	0	0	0	5	25	50	80	95
maximum	0	0	10	30	60	85	100	100

Diameters in millimeters

TERMITE MOUND — SAND — Minimum — maximum

Figure 4.1: Grain size distribution of PTM and Sand

The plot from the sieve analysis is shown in the figure above. Though a relatively wide range of grading for fine aggregates and PTM was used. Some properties to be mentioned are: from table above, the computed values of coefficient of uniformity (Cu= D60/D10) and coefficient of curvature or gradation ($Cc=\frac{D30\times D30}{D60D10}$), obtained from the results of sieve analysis were 4.8 and 1.2 and 2 and 1.07 for termite mound and sand respectively. This results shows that the termite mound is well graded while the sand is loose graded. Also the fineness modulus was 0.85. All these values fall within the range considered for good quality concrete production Mindess, S (2003). It can thus be concluded that both the sand and fine aggregates (sand) is well graded while the termite is loosely graded but when both are compared with the minimum and maximum graded range but fell outside the curves which shows they have similar properties and can thus be concluded that the are both suitable for use in concrete production.

4.1.3 Chemical properties

The result of the chemical analysis conducted to determine the chemical composition of pulverized termite mound is presented in table 4.2

TABLE 4.3: Chemical Properties

CONSTITUENTS	PERCENTAGE COMPOSITION (%)	
	PTM	SAND
CaO	0.89	0.223
SiO_2	69.46	81.49
F_2O_3	5.19	0.487
MgO	0.64	2.275
Al_2O_3	16.46	12.11
SO_3	0.19	2.128
Na_2O	0.31	0.36
K_2O	2.05	1.08
TiO_2	0.58	0.31
LOI	3.53	1.54
INSOLUBLE RESIDUE	1.70	0.00

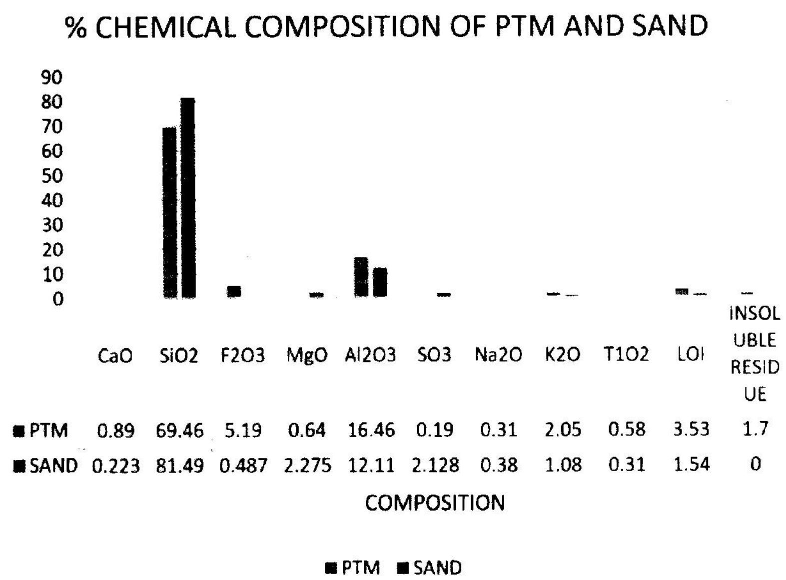


FIG 4.2: CHEMICAL COMPOSITION OF PTM AND SAND

From Table above, it can be seen that the composition of major oxides (SiO_2, CaO and Al_2O_3). In both sand and termite mound are comparable. The chemical composition of the termite mound sample used had silica (SiO_2) content of 69.46%; a combined percentage of silica (SiO_2) and Alumina (Al_2O_3) of more than 70%, a requirement of which a good binder should meet (Syagga *et. al* 2001; Pekmezei and Akyuz, 2004 and Justness *et. al.*, 2005). The composition also meets the requirements of ASTM C 618 (2008) for a combined percentage content of SiO_2, Al_2O_3 and Fe_2O_3 of more than 70% as stipulated. Thus, termite mound can be considered a suitable material for use as a binder. The physical properties as presented in Table 2 indicates a moisture content of 6%; specific gravity and density of 2.19 and 2043Kg/M^3 respectively. The results show that the average SSD density of the termite mound concrete (concrete with PTM as partial fine aggregate) is approximately 2043 Kg/m3 or 20.43 KN/m3. This value is reasonably lower than the average value of 24KN/m3 for traditional concrete produced with cement, sand, and granite. Thus, PTM concrete would produce structural members with lower self-weight than traditional concrete.

Also the loss of ignition, a measure of the extent of carbonation and hydration of free magnesia due to atmospheric exposure for termite mound are less than 3% as set by BS 12 (2003). In addition, the alkalis K_2O and Na_2O with percentages of 2.05% and 0.31% respectively are low, thus reducing the risk of possible destructive alkali-aggregate reactions. The material is free from cyanide which causes corrosion of reinforcement. Pozzolans are a broad class of siliceous and aluminous materials which, in themselves, possess little or no cementitious value but which will, in finely divided form and in the presence of water, reacts chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties.

4.2 Main Investigation

4.2.1 Slump (Workability)

The results for slump shown in Table 4.3 shows that the workability of the concrete mix became more workable upon the introduction of PTM, at 10 % addition of termite mound a 10mm true slump was recorded for all replacement levels of fine aggregates with PTM. A reduced workability was recorded when termite mound was administered above 0%. True slump was recorded when termite mound was administered above 0% for 10% PTM replacement. A slump of 20 mm was recorded for the reference mix.

Figure below is the relationship between PTM addition and the slump (workability) and shows that PTM at 0% true slump was observed but after that rapid decrease was recorded reaching its peak at 50% which was maximum investigated.

This is an indication that inclusion of pulverized termite mound in the mix has no effect on the cohesiveness of the mix has no effect on the cohesiveness of the mix to the extent of causing shear or collapse slump. The effects of PTM on the workability of the concrete, measured in terms of loss of slump, are shown in figure 4.4.

TABLE 4.4: RESULTS FOR SLUMP TEST

REPLACEMENT	SLUMP	TYPE
0	20mm)	TRUE
10	10mm	TRUE
20	5mm	TRUE
30	2mm	TRUE
40	0	TRUE
50	0	TRUE

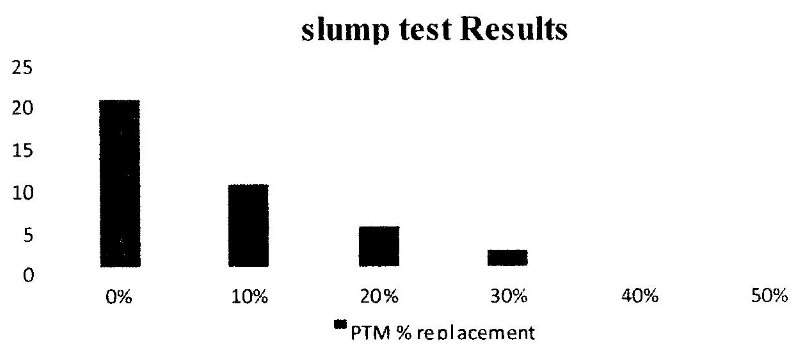


Figure 4.3: Effect of pulverized termite mound (PTM) on the workability of concrete

The figure shows gradual decrease in slump as the percent replacement of fine aggregate with PTM increased. This behavior suggests a dehydrating effect of PTM on the concrete matrix. This finding is in line with the results obtained earlier

(table 4.3) in which PTM was found to be finer than fine aggregate, a phenomenon that give rise to higher surface area, and thus more water demand. The consequence of this behaviour is that, it may result in the reduction in the amount of water available for hydration for the purpose of strength formation, leading to relatively reduced strength development. Thus in using pulverized Termite mound for concrete production, a higher water/binder ratio maybe desired.

4.2.1 Density Results

The effects of pulverized termite mound on the density of the concrete specimen is shown in table below:

Table 4.5: Density test for PTM (for cubes)

	7	14	28	60	90
0%	2348	2353	2376	2373	2427
10%	2345	2349	2370	2338	2424
20%	2352	2356	2356	2353	2430
30%	2336	2347	2373	2377	2430
40%	2342	2350	2358	2415	2427
50%	2337	2344	2361	2403	2430

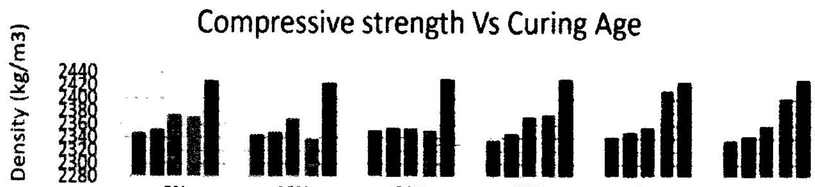
1. Lightweight concrete: These are types of concrete having a density less than $1920Kg/M^3$. Its main property is that they have low thermal conductivity. With the results obtained from above, none of the concrete cube can be classified as lightweight.
2. Normal weight concrete: These are concrete that have a density between 2200 – $2500Kg/M^3$ and a compressive strength between 200 – 500 $Kg/M^3$and a satisfactorily

durability. Most of the results gotten from the concrete cubes can hence be classified as normal concrete.

Results from 7,14,28 and 60 days are all normal concrete.

3. Heavyweight concrete: these are concrete whose density are between 3000 – 4000 Kg/M^3.

   Results shown above shows that all 90 days concrete cubes are heavyweight concrete.



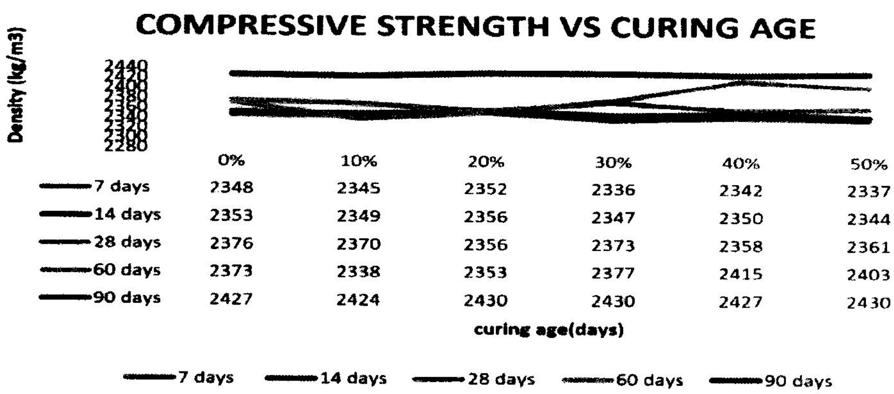
	0%	10%	20%	30%	40%	50%
7 days	2348	2345	2352	2336	2342	2337
14 days	2353	2349	2356	2347	2350	2344
28 days	2376	2370	2356	2373	2358	2361
60 days	2373	2338	2353	2377	2415	2403
90 days	2427	2424	2430	2430	2427	2430

curing age (days)

■ 7 days ■ 14 days ■ 28 days ■ 60 days ■ 90 days

FIG 4.4: Density Vs curing Age

From the figure above, no definite trend was observed at all, the fine aggregate replacement with PTM until 90 days of curing. This could be due to the fact that the cubes used does not have a perfect dimension while the cylinder used also does not have a perfect cross sectional area. The fact that the pulverized termite mound was finer (figure4.2) than sand could also contribute to the higher density as a result of more closely packed matrix. The variation of density of concrete with curing age is shown in the graph above.



	0%	10%	20%	30%	40%	50%
7 days	2348	2345	2352	2336	2342	2337
14 days	2353	2349	2356	2347	2350	2344
28 days	2376	2370	2356	2373	2358	2361
60 days	2373	2338	2353	2377	2415	2403
90 days	2427	2424	2430	2430	2427	2430

FIG 4.5: Density Vs curing Age

Furthermore, the 7,14,28 and 60 days results shows that the concrete cubes can be used for steel structures and many other common concrete structures while 90 days concrete can be used in atomic power plants and other similar structures because it provides good protection from all type of radiation.

4.2.2 Compressive Strength

The compressive strength results obtained shows that PTM is a pozzolana and can replace fine aggregates not lesser than 0% by weight for better results. Compressive strength recorded for PTM at 0%, 10%, 20%, 30%, 40% and 50% replacement have strengths above the reference mix after curing for 7, 14, 28,60 and 90 days. Upon the administration of termite mound, compressive strength improved significantly with 10% PTM replacement having best result at 90 days while 20%, 30% 40% and 50% PTM replacements have their best result **addition of PTM** at 90 days. Table 4.6 shows the compressive strength test results.

TABLE 4.6: Compressive test Results for 7,14,28,60 and 90 *days*

	7 days	*14 days*	*28 days*	*60 days*	*90 days*
0	21.86	25.48	29.10	34.31	35.92
10%	22.97	26.46	29.95	34.95	36.83
20%	23.57	26.79	30.01	35.13	37.20
30%	24.12	28.35	32.58	36.21	37.39
40%	24.34	28.76	33.14	37.00	41.55
50%	24.04	29.01	33.98	38.36	41.83

Relationship between compressive strength and replacement levels of PTM is shown in Figure 4.6 shows the relationship between compressive strength and PTM percentage addition for 7, 14, 28, 60 and 90 days respectively.

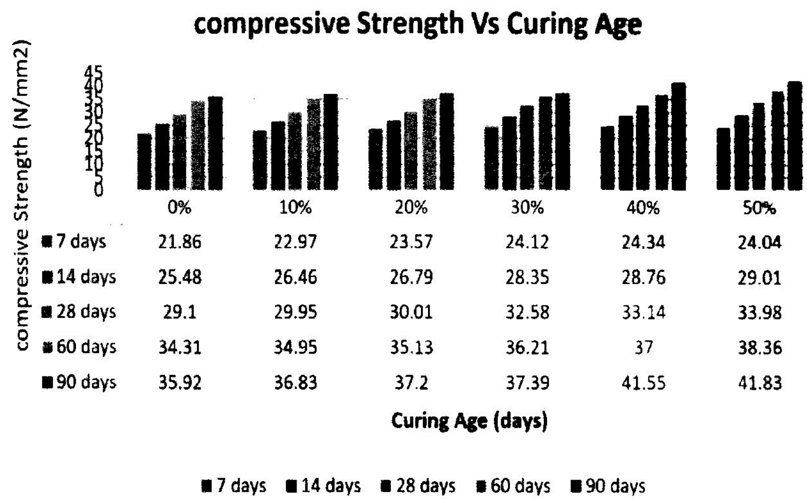


FIG 4.6: compressive strength Vs Curing Age

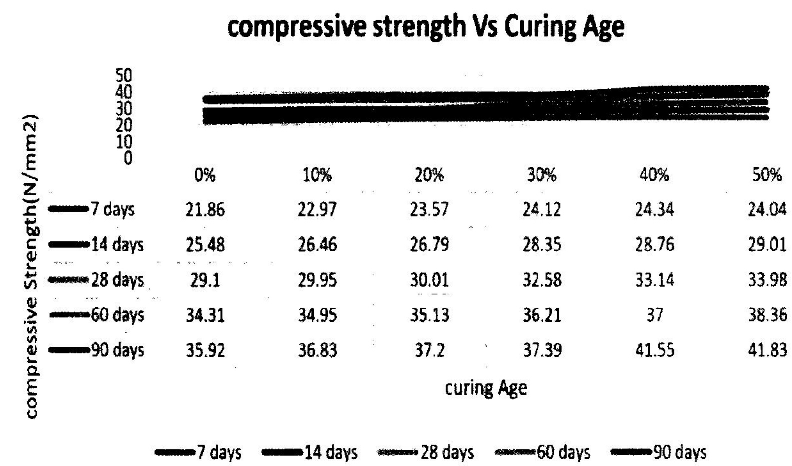


FIG 4.7: compressive Strength Vs curing Age

The compressive strength of mixes having 10% and 20 % PTM replacing fine aggregates shows strength improvement of 25.46 % and 34.13 % respectively above the reference mix after 90 days, while 30% replacement recorded a compressive strength increment also. As the PTM is being administered, workability improved significantly throughout the replacement. However, improved compressive strengths were recorded with respect to the reference mix upon the administration of PTM, 31.58, 32.14 and 37.36 % compressive strength improvement was recorded respectively for 30, 40 and 50 % replacement of fine aggregates with PTM.

4.2.2 Tensile Strength

The results of the tensile strength of concrete incorporating pulverized termite mound measured through the splitting tensile strength as presented in the figure 4.8, from table.

Table 4.7: Results of Tensile strength for the different replacement.

	28 days	*90 days*
0%	2.80	2.75
10%	2.29	2.32
20%	2.53	2.64
30%	2.58	2.59
40%	2.46	2.51
50%	2.14	2.47

It can be observed that the splitting strength increase in fine aggregate replacement with PTM from 10% to 30% and then decrease to 50%, suggesting decreasing tensile strength with the usage of PTM for 28days and 90days. These trend was observed for all the curing ages.

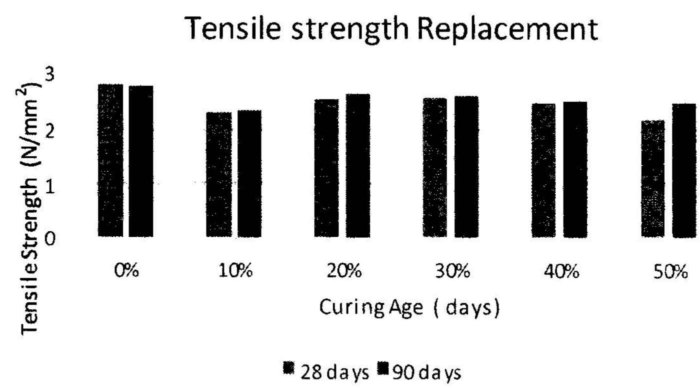
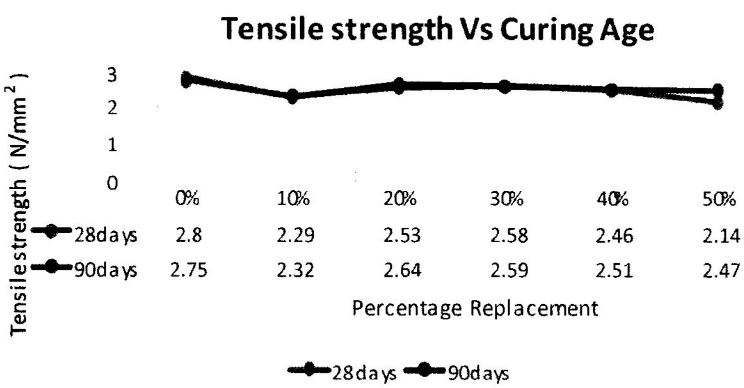


FIG 4.8: Tensile Strength Vs Curing Age



	0%	10%	20%	30%	40%	50%
28days	2.8	2.29	2.53	2.58	2.46	2.14
90days	2.75	2.32	2.64	2.59	2.51	2.47

FIG 4.9: Tensile strength Vs Curing Age

From the table, it can be observed that the ratio of the splitting tensile strength to the compressive strength decrease with the percent decrease in PTM in the mix.

At all the replacement level considered, the ratio were lower than the values obtained for the control specimens. This is an indication of decrement in the tensile performance as the percent fine aggregate replacement with PTM increased.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From results obtained above, the following conclusions can be drawn:

1. The use of pulverized termite mound (PTM) in concrete resulted in concrete with density outside the conventional range value because of its fineness modulus which is lower than that of sand.
2. The inclusion of pulverized termite mound (PTM) has a dehydrating effect on the mix, resulting in linear mix and progressive reduction in workability as the percentage replacement is increased.
3. PTM is pozzolanic in character having satisfied the strength activity index condition set by ASTM C 618 – 08.
4. Replacing fine aggregate with PTM up to 50% resulted in higher compressive strength in relation to the control.
5. Replacing the fine aggregate with PTM up to 50% resulted lower tensile strength in relation to the control.

5.2 Recommendation

Innovative use of pulverized termite mound was used in the production of structural concrete has been presented. Being new in concept, paucity of literature in the area is understandable. Thus, more research work is needed, covering wide range of structural issues such as bending response, shear behavior, beam testing etc. so as to capture the whole structural response of concrete with pulverized termite mound as replacement of fine aggregates. However since the results of this research work shows that the compressive strength increases up to 50% which was the maximum replacement for the research work, hence more research should be done to test for its compressive strength till 100% replacement. Usage of PTM, a waste material in this way, can be of a strategy in the development of an efficient waste management system. It will also help arrest the present uncontrollable usage of natural non-renewable materials in the production of structural concrete.

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