Jimma University

School of Graduate Studies

Jimma Institute of Technology

Faculty of Civil and Environmental Engineering

Construction Engineering and Management Stream

# CALCINED TERMITE HILL CLAY POWDER: AS PARTIAL CEMENT REPLACEMENT IN PRODUCTION OF C-25 GRADE CONCRETE

A Final Thesis submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Construction Engineering and Management)

By:

Guyo Konso Danbala

October, 2017

Jimma, Ethiopia

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Advisor: Prof. Emer T. Quezon

Co-Advisor:  Engr. Getachew Kebede (Ph.D. candidate)

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**APPROVED BY BOARD OF EXAMINERS:**

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# DECLARATION

I, the undersigned, declare that this thesis entitled: **" Calcined Termite Hill Clay Powder: As Partial Cement Replacement In Production of C-25 Grade Concrete.''** is my original work, and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material used for thesis have been duly acknowledged.

Candidate:

**Guyo Konso Danbala**

Signature______________________________

As Master Research Advisors, we hereby certify that we have read and evaluated this MSc research prepared under our guidance, by **Mr.Guyo Konso Danbala,** entitled: **Calcined Termite Hill Clay Powder: As Partial Cement Replacement In Production of C-25 Grade Concrete.''**

We recommend that it can be submitted as fulfilling the MSc Thesis requirements.

**Prof. Emer T. Quezon** _____________ ___10/10/2017__
**Advisor** Signature Date

**Engr. Getachew Kebede, (Ph. D Fellow)** _____________ _____________
**Co- Advisor** Signature Date

# DEDICATION

This work was dedicated to God the Father, God the son, and God the Holy Spirit. You gave me knowledge and understanding which led to the success of this thesis work to secure the title of Master of Science in construction engineering and management. Without You Lord, I would not have been able to move a leap of step in this tough journey. My heart-felt gratitude to You, Lord.

To my beloved Wife-Kabale Wako Sora, I made it thus far through your company. Without your motivations and support, I couldn't have reached this stage. I appreciate you for your prayers and encouragement. Your company has been of tremendous help and worth. I will always love.

To the rest of my family, friends, and mentors, your imports were very helpful. You stood by me and supported me. You had confidence in me and supported me through out.

I highly appreciate you all.

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First and foremost I would like to praise Almighty God for his mercy and steadfast love. Thank You, lord. Am strengthened and supported by your almighty power, thus why am enabled to finish this research paper at the blink of eyes. I bless your holy name forever.

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Lastly, my heart felt appreciation goes to Jimma University School of Graduate Studies, Jimma Institute of Technology, School Civil Engineering, Construction Engineering, and Management Stream by considering the necessity and finally ERA.

May God bless you all.

# *ABSTRACT*

*Cement is one of the components of concrete plays a great role in the construction industry, nevertheless, it is the most expensive and environmentally unfriendly material. Therefore, requirements for economical and more environmental-friendly cementing materials have extended interest in other cementing materials that can be used as partial replacement of the normal Portland cement. This research was, conducted to examine the suitability of calcined termite hill clay powder as a cement replacing material in the production of C-25 grade concrete as relief for this problem.*

*Termite Hill Clay sample was collected from Bokuluboma vicinity. The sample was calcined at the temperature of $650^o{}_C$ using muffle furnace, ground to the fineness of 150 µm and its chemical composition were investigated. Normal consistency and setting time of the pastes containing ordinary Portland cement and calcined termite hill clay powder from 0% to 40% replacement in 5% increment percentage were investigated. The compressive strength of eight different concrete mixes with the CTHCP replacing the ordinary Portland cement were prepared for 22MPa and 34MPa (i.e., for $7^{th}$ and $28^{th}$ days targeted compressive strength) concrete with water to cement ratio of 0.5 and $360kg/m^3$cement content. The properties of these mixes have then been assessed both at the fresh and hardened state.*

*And, the study revealed that calcined termite hill clay powder was found pozzolanic and can partially replace cement. It has shown that up to 11.3% replacement of the ordinary Portland cement by CTHCP, the cubes achieved a target mean compressive strength of C-25 grade concrete at $28^{th}$ day 34Mpa. Although, the replacement percentage greater than 11.3% of the cement by calcined termite hill clay powder in the concrete has shown a slightly lower compressive strength. Moreover, the mix was found workable up to 25% replacement percentage and also the setting time of the pastes containing calcined termite hill clay powder found faster than that of the control mix.*

*Finally, it can be concluded that CTHCP was suitable to partial replace cement, 11.3% replacement of cement by calcined termite hill clay powder was optimal percentage for the production of C-25 grade concrete, the mix was workable up to 25% replacement and this mineral admixture found set accelerator suitable for cold weather concreting.*


***Keywords;*** ***Concrete Grade C-25, Partial Replacements, Calcined Termite Hill Clay Powder, workability, Compressive Strength, Setting time***

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# ACRONYMS

| | |
|---|---|
| AASHTO | American association of state highway and transportation officials |
| AAS | Atomic Absorption Spectrophotometry |
| $Al_2O_3$ | Aluminum Oxide |
| ASTM | American Society for Testing and Materials |
| BS | British Standard |
| CA | Coarse Aggregate |
| $CaCO_3$ | Calcium Carbonate |
| $C_3S$ | Tricalcium Silicate |
| $C_2S$ | Dicalcium Silicate |
| $C_3A$ | Tricalcium Aluminate |
| $C_4AF$ | Tetra Calcium Aluminum Ferrite |
| C–S–H | Calcium Silicate Hydrate |
| $CO_2$ | Carbon dioxide |
| CaO | Calcium Oxide |
| CTHCP | Calcined Termite Hill Clay Powder |
| FA | Fine Aggregate |
| $Fe_2O_3$ | Ferric Oxide |
| $H_2O$ | Hydrogen Oxide |
| IS | International Standard |
| JMC | Joshi and Mogi Construction Private Limited Company |
| $K_2O$ | Potassium Oxide |
| L.O.I | Loss of Ignition |
| MgO | Magnesium Oxide |
| MnO | Manganese Oxide |
| MPa | Mega Pascal |
| $Na_2O$ | Sodium Oxide |
| OPC | Ordinary Portland cement |
| $P_2O_5$ | Diphospharus Penta Oxide |
| $SiO_2$ | Silicon Oxides |
| TMS | targeted mean strength |
| $TiO_2$ | Titanium Oxide |
| W/B | Water Binder Ratio |

# CHAPTER ONE

# INTRODUCTION

## 1.1. Background to the study

Construction industry is one of the booming economic sectors on the global world now a day. This comprises of both construction of vertical and horizontal structures. In Ethiopia it has been happened the same, since the governmental policy support infrastructure development projects in order to realize the transformation from agriculture to industry. Hence, Concrete is probably the most commonly used construction material in the world (Sasturkar P.J., et al., 2011). For desired characteristics of concrete, many research and modifications have been made in concrete. There is always a requirement for concrete with high durability and strength. For this requirement, blended cement concrete has been introduced. Pozzolanas, also known as cementitious materials, are used in concrete constituent with normal cement as replacement materials.

Originally the term pozzolanas was associated with calcined earth and volcanic ashes which normally react with lime in the presence of water at ambient temperature. Nowadays, this term covers all aluminous/siliceous materials which are in fine powder form and react with calcium hydroxide in the presence of water to form compounds which have cementitious properties. Concrete is a mixture of cement, aggregates (Coarse and fine), and water, with or without addition of admixtures. Cement is main constituent of concrete. The use of cement in concrete is increasing with time, but there have been some environmental concerns in terms of damage caused by extraction of raw materials and emission of $CO_2$ during cement manufacturing process. There is always pressure on construction industry to reduce the consumption of cement because each ton of cement produces approximately 1 ton of $CO_2$, mainly from the burning of fossil fuels and from the de-carbonation of limestone (Rehan R.and Nehdi M., 2005). On the other side Cement which is one of the components of concrete plays a great role, but is the most expensive and environmentally unfriendly material. Therefore requirements for economical and more environmental-friendly cementing materials have extended interest in other cementing materials that can be used as partial replacement of the normal Portland cement (Biruk, 2011). Ground granulated blast furnace slag, fly ash; silica fume, etc. have been used successfully for this purpose (Juenger, et al, 2012).It is a very Contemporary trends, that in some parts of the world termite hill clay soils, which is the earth piling materials (fig.1.1) mostly populated in arid and semi-arid areas, has been tested for its pozzolanic property and found to improve some of the properties of the paste, mortar and concrete like compressive strength in certain replacement percentages and fineness (Meshack, et al., 2015). However, this is somewhat a new concept in Ethiopia as long as nothing has been done with both inactive (uncalcined) and active (calcined) termite hill clay powder as partial cement replacement in production of C-25 grade concrete for this matter.

**Fig.1.1. Termite hill material**

Quite a fact and also the believe of Many research scholars that use of Pozzolana can permit a decrease in the use of Portland cement when producing concrete; this is more environmentally friendly than limiting cementitious materials to Portland cement. As experience with using Pozzolana has increased over the past 15 years, current practice may permit up to a 40 percent reduction in Portland cement used in the concrete mix when replaced with a carefully designed combination of approved pozzolanas according to ASTM C 618:1980. Since, there is need for sustainable and environmental friendly materials in the world due to increase of pollutant at alarming rate.

Therefore, this research study have revealed the advantage of using calcined termite hill clay powder populated in southern parts of Ethiopia specifically around Bokuluboma, which is in Oromia regional state, Borena zone, Miyo Woreda, as a pozzolanic material to partial replace cement. An experimental investigation was carried and the impact of adding calcined termite hill clay powder was examined as it improve some mechanical and physical properties of concrete such as consistency, setting time, workability, and compressive strength. In addition, the comparison of the experimental result with that of literature and standard also done to strengthen the arguments.

### 1.2. Statement of problem

Among concrete ingredients, cement is one of the raw materials that is used in the mix and acts as a binder between sand and aggregate. Though, it has been criticized by some researchers on green environment grounds. This criticism was levelled based on the production of Portland cement which caused greenhouse emission: a phenomenon which contributes to global warming. According to some researchers, the production of a tonne of Portland cement generates about one tonne of carbon dioxide ($CO_2$) to the atmosphere and it is of 5% of global $CO_2$ emission (Ahmad, 2015).This implies that gas emission is directly proportional to the quantity of cement produced. In country Ethiopia, the problem is similar to that of the global world, due the expansion of cement manufacturing industry. And it shows that the cement industry extremely pollute the environment by releasing this pollutants. Nevertheless, the major concern of today's world is to relief the environment, seeking appropriate solution for things contributing the problem. This might hinders the sustainability of the cement industry and that of concrete in the near future. However, Apart from environmental concerns regarding $CO_2$ emission during cement manufacturing, rapid consumption of natural resources also makes cement expensive when compared with aggregates and water in production of concrete. Therefore, this study was done on the termite hill clay powder and has revealed the use of local available materials, in this case calcined termite hill clay powder, to produce sustainable concrete by pretending to reduce the amount of cement produced, and in other way while maintaining sustainable development has thus been an important issue.

### 1.3. Research Questions

The question researched in the course of this thesis work was the followings;

1) Does the calcination of termite hill clay powder contribute to the chemical properties of the clay soils that significantly differ from those present in ordinary clay?
2) Can calcined termite hill clay powder be used as partial cement replacements as sustainable material for production of C-25 grade concrete?

3) Can termite hill clay resource be conveniently converted into locally available affordable construction materials in partially, replacing cement in production of C-25 grade concrete?

## 1.4. Objectives

### 1.4.1. General Objective

To assess the suitability of calcined termite hill clay powder (CTHCP) as partial replacement of cement in production of C-25 grade concrete.

### 1.4.2. Specific Objectives

- ✓ To determine chemical properties of calcined termite hill clay powder that will be used as partial replacement of cement in production of C-25 grade concrete.
- ✓ To determine the workability and compressive strength of concrete produced with calcined termite hill clay powder as partial cement replacement.
- ✓ To investigate the optimal percentage of mix when calcined termite hill clay powder is used as partial replacement in cement for production of grade C-25 concrete.

## 1.5. Significance of the Study

Global Production of cement can be a major concern to environment because of the greenhouse gases released from cement manufacturing industry. Even though, In Ethiopia this industry coverage was limited yet, but the future needs of the products lead to the expansion of the industry which might aggravate the problem. Therefore, This study have assessed the suitability of calcined termite hill clay powder as partial replacement materials for cement in concrete production being under the umbrella of standard set criteria and had benefited the following:

- ✓ The Environment by paving the way to the production of green concrete since the termite hill clay is the sustainable materials for construction.
- ✓ Borena zone and other semi-arid areas in Ethiopia where termite hill clay resource is abundantly exist, since these materials can replace cement in some percentages for concrete production.
- ✓ The small-scale industry sectors from employments side, the calcination and grinding of termite hill clay to the fineness of cement needs human power in addition to machine before replacing the cement in concrete batching plants.

- ✓ Also help other research scholars being as reference materials for the same thematic areas.

## 1.6. Scope of the study

As the title of the thesis reveals, the goal of the research is to study suitability of calcined termite hill clay powder for replacing cement in production of C-25 grade concrete, a special emphasis to its pozzolanic property, compressive strength of the mix percentages and optimal mix for production of this structural concrete. To study all concrete properties, it requires studying and/or conducting laboratory tests on these entire properties that in turn require great deal of time, effort, enough budget and other resources that are absolutely beyond the scope of this research.

Hence, although in some cases other characteristics may be important, the strength of concrete is commonly considered as its most valuable property. Furthermore, strength usually gives an overall image of the quality of concrete, and it is considered as good index whether direct or inverse, of most of the other properties (Mikiyas, 1987). Therefore, the research mainly focused on the compressive strength of concrete produced by cement partial replaced with calcined termite hill clay powder. Literature review on cement and concrete making materials, study on the supplementary cementitious materials, termite hill materials and laboratory tests on compressive strength of concrete cubes produced from the pure cement and that of replaced in percentage with calcined termite hill clay powder are the bases to evaluate mainly the compressive strength and partly other properties of the concretes produced using the cements.

The research was, therefore, made based on not only laboratory test results but also literature surveys on calcined termite hill result analysis.

i. Termite hill clay powder (THCP) is available in many counties in arid and semi-arid areas in Ethiopia like, Afar and some parts of Hararghe but the sample that used in this research, was brought from Bokuluboma around Didachina, Southernmost of Oromia Region, Miyo Woreda Borena Zone. It is expected that termite hill clay powder from other parts of the country had similar properties. For this research, only calcined termite hill clay powder was used.

ii. The researcher has checked the strength of the samples at age of 7 and 28 days only. It is a well-known fact that concrete attains optimal strength after 28 days of curing.

### 1.7. Limitation of the study

The limitations of this research were noted on the following areas;

- ✓ Unavailability of larger size furnace in the laboratory forced the researcher to use small muffle furnace which consumed great deal of time during calcination of termite hill clay sample at required temperature.
- ✓ Manually, grinding of calcined termite hill clay powder (CTHCP) made it difficult to achieve uniform fineness (fig.1.2.). The use of electronic grinder which was not available in the JMC project laboratory could have made all samples uniformly fine.
- ✓ Delay and bureaucracy complexity of research fund have also challenged the progress of the research work (i.e. time).

**Fig.1.2. Manual grinding of calcined termite hill clay**

# CHAPTER TWO

# REVIEW OF RELATED LITERATURE

Cement and it product concrete have counted several years after ventured into a new territory of improvement. Among this improvement the use of mineral admixture materials as partial replacement of cement is the case to reduce the negative environmental effect of the cement production and the cost of cement itself. The materials used as cement replacements were reported to improve different properties of the mortar and the concrete according to Jan R. et al., 2005.Hence, under this chapter cement, concrete, pozzolanas and termite hill clay soils was discussed with the argument of this research work.

## 2.1. Cement

Cement in general can be described as a material with adhesive and cohesive prosperities which make it capable of bonding mineral fragments into a hard continuous compact mass. The first production of cement started when Romans, mixed lime ($CaCO_3$) with volcanic ash, producing cement mortar which was used during construction of monumental structures as the Coliseum (Peter Hewlett, 2004). In addition to this Cement is also defined as the chemical entity formed from predetermined ratios of reactants at fairly precise temperature. Naik T. et al. reported that in 2006, the worldwide cement clinker production was approximately 1.6 billion tons. Mixed with water and aggregates, the resulting concrete is second only to water as the most consumed substance on Earth (International Finance Corporation, World Bank group).Ordinary Portland cement results from the calcination of limestone and silica are given in the following reaction:

Limestone + Silica (1450$^{o}$C) ═ Portland cement + Carbon dioxide

$5CaCO_3 + 2SiO_2 \rightarrow (3CaO.SiO_2)\ (2CaO.SiO_2) + 5CO_2$ (Equation 2.1)

The production of one ton of cement produces 0.55 tons of chemical $CO_2$ in a reaction that takes place at 1450 degrees centigrade. An additional 0.4 tons of $CO_2$ is given as a result of the burning of carbon fuel to provide this heat (Davidovits, J. 1994). Due to this problem the researcher had relieved the environments and lessened the cost of cement production by using calcined termite hill clay powder which used for partial replacement of cement to reduce the emission of carbon dioxide. Therefore, the research considered significant because it deals with solving the issue of overdependence on cement while at the same time tried to produce sustainable materials for concrete production.

### 2.1.1. Types of cement

Though there are various types of cements used for concrete production, Portland cement is the one which is commonly used in Ethiopia for concrete production.

### 2.1.2. Portland cement

It is cementing materials resembling a natural stone quarried form Portland in UK. Portland cement may defined as product obtained by finely pulverizing clinker produced calcining incipient fusion, an intimate and properly proportioned mixture of argillaceous and calcareous materials (S.K. Duggal,2008). Portland cement is one of the Hydraulic cements which are capable of setting and hardening under water. It can also be used for mortar & plaster production. It is used in all types of structural concrete like walls, floors, bridges, tunnels, etc. It is further used in all types of masonry works like foundations, footings, dams, retaining walls, and pavements. When Portland cement is mixed with sand and lime, it serves as mortar for laying brick and stone; and when it is mixed with coarse aggregate and fine aggregate (sand) together with enough water, to ensure a good consistency, we get concrete.

The origin of the name "Portland cement" is usually attributed to Joseph Aspdin, a brick mason in England who in 1824 took out a patent for making a powder made from mixed and ground hard limestone and finely divided clay. This forms into the slurry and then is calcined in a furnace till the $CO_2$ was expelled. He called the resulting material Portland cement because when the mortar made with it hardened it produced a material resembling the stone which was quarried near Portland, England (Shetty M.S., 2005).

### 2.1.3. Chemical composition of Portland cement

The major constituents of raw materials used in Portland cement production; mainly, lime, silica, alumina and iron oxide compounds interact with one another in the kiln to form a series of more complex products. Which are usually regarded as the major constituents of cement. These are the tricalcium silicate ($C_3S$), Dicalcium silicate ($C_2S$), tricalcium aluminate ($C_3A$) and tetra calcium aluminoferite or iron compound ($C_4AF$) (Neville, A.M, 1994).

**Table 2.1 Approximate oxide composition limits of Portland cement**

| *Oxide* | *Content in percent* |
|---|---|
| **CaO** | 60 -67 |
| **$SiO_2$** | 17-25 |
| **$Al_2O_3$** | 3 - 8 |
| **$Fe_2O_3$** | 0.5 - 6 |
| **MgO** | 0.1 - 4.0 |
| **A1kalis** | 0.2 - 1.3 |
| **$SO_3$** | 1-3 |

Another most common classification of Portland cement is that of ASTM. It classifies Portland cement mainly into five groups (non-air entrained) differing only in the relative amount of the compounds and the degree of fineness.

- ✓ ASTM type I cement is a general purpose Portland cement used when there is no special property required by the concrete.
- ✓ ASTM type II cement is Moderate Portland cement. It is also a general-purpose cement to be used when moderate sulfate resistance or moderate heat of hydration is desired.
- ✓ ASTM type III cement is High early strength Portland cement which is used when high early strength is desired, usually less than one week; it is usually used when a structure must be put into service as quickly as possible.
- ✓ ASTM type IV cement is Low -Heat of Hydration Portland cement which is used, when a low heat of hydration is required, like in mass concrete.
- ✓ Finally, ASTM type V is Sulfate -resisting Portland cement which is used when high sulfate resistance is desired.

In this research type I cement was used which is Dangote ordinary Portland cement (42.5N) in proportioning the mix of the concrete cubes for determination of compressive strength and workability

### 2.1.4. Portland Pozzolana cement

Portland pozzolana cement (PPC) is manufactured by the inter grinding of OPC clinker with 15 to 35 % of pozzolanic materials (Shetty M.S., 2005). Pozzolanic materials are siliceous or aluminous materials which by themselves possess little or no cementitious properties [ASTM C618]. But in the presence of water, they react with calcium hydroxide which is liberated from the hydration of cement to form a compound possessing cementitious property.

The reaction of the pozzolanic materials with calcium hydroxide results in many advantages of PPC over OPC. If these pozzolanic materials were not reacted with the calcium hydroxide, free calcium hydroxide would have been present in the concrete resulting in higher permeability of the concrete and susceptibility to other attacks. The pozzolanic reaction reduces the porosity of the concrete by producing the cementitious compound. It also reduces the heat of hydration since its reaction is slower than that of OPC, which implies that it has the slower rate of strength than OPC, making it suitable for mass concrete construction (Biruk, 2011). In addition to these cement types; there are also other types of cement which are produced by either adding other materials to the clinker or by forming other compounds during burning. They are collectively called modified Portland cement. Expansive cement, calcium sulfoaluminate cement, masonry cement, oil well cement, white cement, etc. can be an example for this. There is also non-Portland inorganic cement which is used to some extent.

### 2.1.5. Hydration of cement

Hydration is the reaction in which cement becomes a bonding agent takes place in a water cement paste or the process in which in the presence of water, the silicates and aluminate compounds of cement form products of hydration, which in time produce a firm and hard mass (Adisu, 2014).Hydration is fast during the first few minutes of mixing and decreases continuously with time. Because of reduction in rate of hydration even after a long time there remains an appreciated amount of unhydrated cement. Hence there is hydration at any time after hardening of concrete though it is at a very lower rate (Portland cement Association, 2005). Similarly, hydration of cement started when water and Portland cement are mixed, the constituent compounds of the cement and the water undergo a chemical reaction resulting in hardening of the concrete.

This chemical reaction of the cement and the water is called hydration, and it results in new compounds called hydration products. Both $C_3S$ and $C_2S$ react with water to produce an amorphous calcium silicate hydrate known as C–S–H gel which is the main „glue" which binds the sand and coarse aggregate particles together in concrete. Each of the compounds found in the cement reacts with water, but the rate at which they react is different. $C_3S$ and $C_3A$ are the most reactive compounds, whereas $C_2S$ reacts much more slowly. Approximately half of the $C_3S$ present in typical cement will be hydrated by three days and 80% by 28 days, in contrast, the hydration of $C_2S$ does not normally proceed to a significant extent until approximately 14 days (John Newman and Ban Seng Choo, 2002). Gypsum is added to lower the rate of hydration of $C_3A$.

After a rapid initial reaction, $C_3S$ will pass through a dormant stage which has a practical significance because it allows concrete to be placed and compacted before setting and hardening commences.

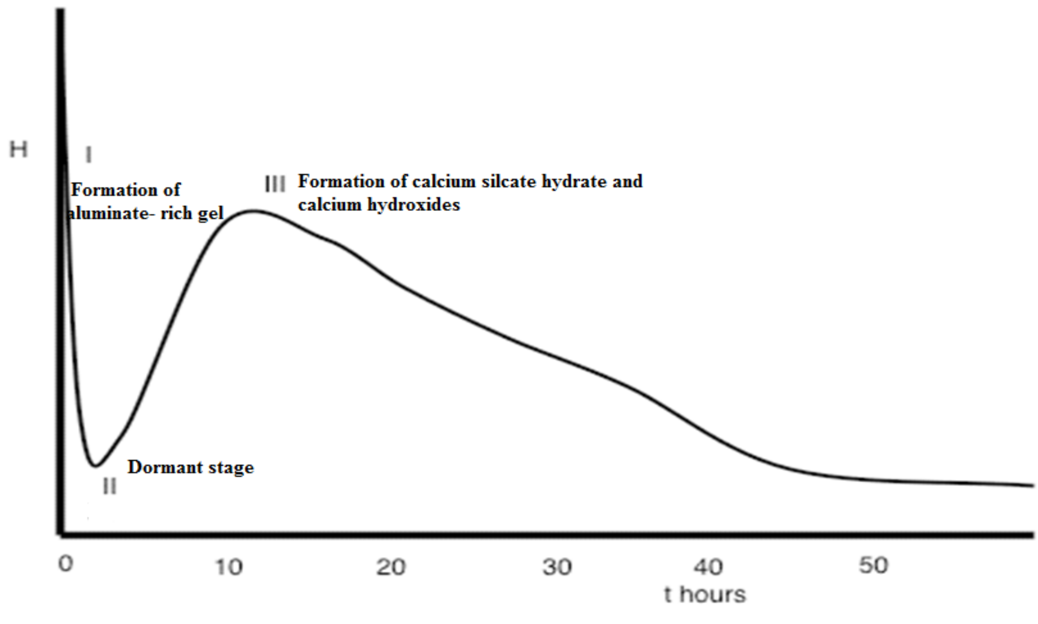



**Fig 2.1. Graph of Cement hydration process**

The rate and amount of heat of hydration are affected by various factors. Among these cement composition and fineness, water to cement ratio of the concrete, the age of the paste and ambient conditions are the most common ones. Varying the cement composition affects the rate of reaction because the different compounds present in the cement have different speed of hydration. The hydration of Portland cement as a whole is more complex than the individual compounds. This is because the different compounds have different products, reaction rate, and each of the compounds consumes water. When cement is first mixed with water some of the added calcium sulfates, dissolve rapidly. The purpose of adding calcium sulfate is to retard the hydration of $C_3A$, which without calcium sulfate results in flash set due its high rate of reaction with water.

This is because $C_3A$ is more reactive than any of the compounds in the cement and if allowed will take much of the water. The order of reaction is $C_3A > C_3S > C_4AF > C_2S$ (Sidney Mindess, et al., 2003). But the rate of hydration of these compounds differs from cement to cement depending on the fineness, the rate of cooling of the clinker and other factors like presence of impurities and other cement compounds.

#### 2.1.6. Physical properties of cement

The manufacture of cement requires stringent control, and a number of tests are performed in the cement works laboratory to ensure that the cement is of the desired quality and that it conforms to the requirements of the relevant national codes and standards. These tests are; consistency test, fineness test, setting time test (Abebe Dinku, 2002). In this research work the quality of cement was determined by the following tests.

##### 2.1.5.1. Fineness

The fineness of cement affects many of its properties. The heat released and the rates of hydration are the main properties which are affected by the fineness of cement. These properties of the cement, in turn, affect many other properties, like normal consistency, setting time, strength, etc. The fineness of cement can be measured mainly by specific surface area method and particle size distribution. The specific surface area is the summation of the surface area of all of the particles in 1 gm or 1 kg of cement. Most of the time, it is a general practice to describe fineness by a single parameter, specific surface area (Sidney Mindess, et al., 2003). Although it is possible to measure the particle size distribution of cement, there is still no agreement on what would contribute the best grading curve for cement. Due to this and other factors, the specific surface area is preferred over the particle size distribution. The surface area is measured by the Blaine air-permeability test (ASTM C 204 or AASHTO T 153) that indirectly measures the surface area of the cement particle per unit mass.

According to the Ethiopian standard ordinary Portland cement shall have a specific surface area of not less than 225$m^2$/kg (Abebe Dinku, 2002), whereas the ASTM C 204 standard recommends a minimum of 260 $m^2$/Kg.

### 2.1.5.2. Consistency of cement paste

Many of the properties of concrete are affected by its water content. The physical requirements of cement paste like setting and soundness depend on the water content of the neat cement paste. Therefore it is necessary to define and study the water content at which to do these tests. This is defined regarding the normal consistency of the paste which is measured according to ASTM C 187. The amount of water required to achieve a normal consistency as defined by a penetration of 10 ± 1 mm of the Vicat plunger (ASTM C 187) is expressed as a percentage by weight of the dry cement, the usual range being about 25% to 33% (Abebe Dinku, 2002). The test is very sensitive to the conditions under which it is being carried out, particularly the temperature and the way the cement is compacted into the mold. The test does not correlate to the quality of the cement; it only measures the plasticity of cement paste.

### 2.1.5.3. Setting time

The setting is a process in which cementitious mixtures of plastic consistency is converted into a set material which has lost its deformability and crumbles under the effect of sufficiently great external force . It is preceded by a stiffening of the paste in which the apparent viscosity of the material increases without losing its plastic character. There are two types of setting time, i.e., initial and final setting times. The initial setting time indicates the time at which the paste begins to stiffen considerably and can no longer be molded; while the final setting time indicates the time at which the paste has hardened to the point at which it can sustain some load. Like normal consistency, these tests are also used for quality control. Ethiopian standard recommends that the initial setting time for cement not to be less than 45 minutes and the final setting time not to exceed 10 hours (Abebe Dinku, 2002).

## 2.2. Concrete

Concrete is the most important and major construction material which is used universally. It is widely used in almost every type of construction among others, building, infrastructure and structures which are used to protect from rough environment and other developments.

It became an important material in construction industry based on its strength of being able to support higher load and its durability against the environment compared to the other material. On the other hand, the usage of concrete for developmental purposes is double the usage of other material such as wood, glass and steel. Concrete is a manufactured product which consists of raw material such as cement, sand, aggregate and some admixture to improve the characteristic of concrete. High demand for concrete increases the use of raw materials in the mixture of concrete (Ahmad, 2015).

The word concrete comes from a Latin word ‘concretus’ which means to grow together (Sidney Mindess, et al., 2003)., which implies that it is a composite of different materials. It is composed of the coarse granular material called aggregate or filler which is embedded in a hard matrix of material (cement or binder with water) binding the aggregates together and filling the space formed between them. When the constituents are mixed with water, the concrete solidifies and hardens due to a chemical reaction between the water and the cement called hydration, which finally forms a stone-like material by binding the aggregates together.

Concrete is mainly composed of cement, aggregate, and water. Cementitious materials, pozzolanic materials, filler materials, chemical admixtures, and some other additives may also be the constituents of concrete depending on the need and their availability. All the constituents have their purpose in the concrete. Cement with water acts as a binding medium in which the aggregates which account 70% to 80% of the concrete are bound together to form the concrete. Economy, dimensional stability, and wear resistance are the main reasons behind using aggregates. Different types of admixtures are used to modify the properties of ordinary concrete to make it suitable for any situation. If concrete is to be suitable for a particular purpose, it is necessary to select the constituent materials and combine them in such a manner as to develop the special qualities required as economical as possible. Therefore the selection of constituents of concrete depends on the quality and economy of the particular concrete required.

**2.2.1 Strength of concrete**

The strength of concrete is commonly considered its most valuable property, although in many practical cases other characteristics, such as durability and permeability, may, in fact, be more important. Nevertheless, strength usually gives an overall picture of the quality of concrete because it is directly related to the structure of the hardened cement paste (Neville, A.M., 1994).

The strength of concrete is dependent on many things. The hydration reaction, water to Cement ratio, aggregate type, amount and size, water content, cement content, curing condition, cement type, compaction method used, etc. affect the strength of concrete. Strength at any W/C ratio depends on the degree of hydration of the cement and its physical and chemical properties. The decrease in the water content of the concrete results in a higher strength of the concrete. The water required for the hydration reaction is less than that of the mixing water; the extra water provided is used to make the concrete more workable. The compaction of the fresh concrete reduces the amount of entrapped air and therefore increases the strength of the concrete. It is found that for each 1 % of air entrapped there will be a 5 to 6 % loss of strength (Abebe Dinku, 2002).. Curing temperature affects the hydration of cement and hence the duration of strength gains. Cubes kept at about $10^{o}$C will have their seven-day strength reduced by 30% and their 28-day strength by 15% (John Newman and Ban Seng Choo., 2003). Different pozzolanic materials have the different effect on strength. But most of them including calcined termite hill clay powder have been found to improve the strength of concrete, especially at latter days due to the secondary reaction.

### 2.2.2. Workability of concrete

Workability is the measure of how easy or difficult it is to place, consolidate and finish concrete. It contains in it different aspects like consistency, flow ability, mobility, compact ability, finish ability, and harshness (Sidney Mindess., et al., 2003). It can also be defined regarding the amount of mechanical work, or energy required producing full compaction of the concrete without segregation. This property of concrete is affected by some factors like water content of the mix, mix proportions, aggregate properties, time, temperature, characteristics of the cement and admixtures. Water content is the most important factor affecting the workability of concrete. Increasing the amount of water will increase the workability of the concrete. However, the increase in water content of the mix will decrease the strength and also result in segregation and bleeding. When considering the effect of aggregate the amount of aggregate, the proportion of coarse and fine aggregate and the shape and texture of the aggregate particles affect the workability of concrete. Keeping the water content and cement content constant increasing the amount of aggregate reduces the workability of concrete. The spherical and smooth aggregate result in a more workable mix, whereas flat, elongated and rough aggregate particles will result in the reduction of workability. The increase in the ambient temperature will reduce the workability of the concrete, due to the increase of evaporation and rate of hydration caused by the higher temperature. The cement content and cement replacing materials also affect the workability. Higher cement content reduces workability. The effect of cement replacing materials depends on their nature. Finer materials result in the reduction of workability while spherical materials increase it.

### 2.3. Pozzolanas

The modern concrete technology uses different types of admixtures to enhance the properties of the fresh and hardened concrete. Mineral admixtures are one of these admixtures used in concrete for a variety of purposes. They may be found naturally or artificially. These admixtures can be divided into three main categories, which are pozzolanic, cementitious and non-reactive materials. The first two categories are added at the mixer as supplementary cementing materials. These admixtures interact chemically with the hydrating Portland cement and form a modified paste microstructure. The non-reactive admixtures are on the other hand finely divided materials such as lime-stone, silica flour, hydrated lime, etc., which may sometimes react weakly with the cement. They are blended with Portland cement to form masonry cement which has improved workability. In this research, the researcher had concerned with pozzolanic admixtures as described below.

#### 2.3.1. Pozzolanic materials

Pozzolanic materials are siliceous or siliceous and aluminous materials which alone possess little or no cementitious value but will, in finely divided form and the presence of moisture, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties (Moises. 2007). Their recognition dates back long ago to the ancient Greeks and Romans. The Greeks used volcanic ash, and the Romans adopted and extended the Greeks technology using ash from varieties of sources around their living environments.

Pozzolanic materials can be divided into two groups: natural pozzolana and artificial pozzolana. Clay and shales, opaline chert, diatomaceous earth, and volcanic ash are an example of natural pozzolans while fly ash, blast furnace slag, silica fume, rice husk ash, and metakaolin are the example of artificial pozzolans. Most of the pozzolans in use today are mainly byproduct materials that are widely available. Because of the diversity of pozzolans their chemical composition also varies. Therefore classifying pozzolans only depending on their chemical composition would be difficult. For this reason, ASTM C 618 classifies pozzolans depending on the performance basis. ASTM C 618 chemical composition for pozzolans is as shown in Table 2.2.

**Table 2.2. ASTM C 618 chemical requirement for Pozzolana (ASTM, concrete and mineral admixtures, 1972)**

| Chemicals | Pozzolan Class | | |
|---|---|---|---|
| | N | F | S |
| $SiO_2+Al_2O_3+Fe_2O_3$ (min %) | 70.0 | 70.0 | 70.0 |
| MgO (max %) | 5.0 | … | 5.0 |
| $SO_3$ (max %) | 4.0 | 5.0 | 4.0 |
| Moisture content (max %) | 3.0 | 3.0 | 3.0 |
| Loss on ignition (max %) | 10.0 | 12.0 | 10.0 |
| Available alkalis as $Na_2O$ (max %) | … | 1.5 | 1.5 |

The reason behind using pozzolans is the improvement found in both the fresh and hard concrete. Lowering of the heat of hydration and thermal shrinkage, increase in water tightness, reduction in the alkali-aggregate reaction, resistance to sulfate attack, better workability, and cost efficiency are some of the improvements achieved by using pozzolans blended with Portland cement.One of the common materials classified as cementitious is pozzolana which is the natural or artificial material containing silica in a reactive form. A more formal definition of ASTM 618-88a describes pozzolana as a siliceous or siliceous and aluminous material which in itself possesses little or no cementitious value but will, in finely divided form and the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties. It is essential that pozzolana is in a finely divided state as it is only then that the silica can combine with calcium hydroxide (produced by the hydrating Portland cement) in the presence of water to form stable calcium silicates which have cementitious properties. We should note that the silica has to be amorphous, that is, glassy because crystalline silica has very low reactivity.

Broadly speaking, pozzolanic materials can be natural in origin or artificial. The natural pozzolanic materials most commonly met with are volcanic ash-the original pozzolana-Pumicite, Opalineshales and Cherts, Calcined diatomaceous earth, and Burnt clay. ASTM C 618-08a describes these materials as class N. Some natural pozzolanas may create problems because of their physical properties, e.g., diatomaceous earth, because of its angular and porous form, requires high water content.Certain natural pozzolanas improve their activity by calcination in the range of 550 to 1 100˚C depending on the material. For an assessment of pozzolanic activity with cement, ASTM C 311 -07 prescribes the measurement of a strength activity index. This is established by the determination of strength of mortar with a specified replacement of cement by pozzolana. The outcome of the test is influenced by the cement used, especially its fineness and alkali content. There is also a pozzolanic activity index with lime which determines the total activity of pozzolana. The pozzolanic of pozzolanic cement, that is, cements containing between 11 and 55 per cent of pozzolana and silica fume according to BS EN 197- 1:2000, is tested according to BS EN 196-5:2005, the test compares the quantity of calcium hydroxide in an aqueous solution in contact with the hydrated pozzolanic cement, with the quantity of calcium hydroxide which saturates a solution of the same alkalinity. If the former concentration is lower than the latter, then the pozzolanicity of the cement is considered to be satisfactory. The underlying principle is that the pozzolanic activity consists of fixing of calcium hydroxide by the pozzolana so that the lower the resulting quantity of calcium hydroxide the higher the pozzolanic. Pozzolanicity is still imperfectly understood; specific surface and chemical composition are known to play an important role but, because they are inter-related, the problem is complex. It has been suggested that, in addition to reacting with $Ca(OH)_2$, pozzolanas also react with $C_3A$ or its products of hydration (Neville., 1987). Therefore, the calcined termite hill clay has been assessed for pozzolanic effect on the mix of the concrete.

### 2.3.2. Pozzolanic reaction

The hydration of tri-calcium silicate and di-calcium silicate with water gives calcium silicate hydrate and calcium hydroxide. The first compound has very low solubility in water while the later one is very much soluble in water and has no cementitious value and is found as a free lime in the concrete, resulting in the porosity of the concrete, which in turn results in durability problems. The siliceous and aluminous compounds found in the pozzolan in a finely divided form react with the calcium hydroxide to form highly stable cementitious substances of complex composition involving water, calcium, and silica. Finely divided pozzolans and amorphous silicates result from a better pozzolanic reaction. The principal reaction taking place is as shown below.

Pozzolan + Calcium Hydroxide + water --------------------Calcium Silicate Hydrate (gel)

S + CH +H………………. …………………………………………C-S-H (Equation 2.2)

This reaction is called pozzolanic reaction. It results in the consumption of the calcium hydroxide produced by the hydration of the cement and as a result lowers its amount in the concrete. The C-S-H formed in this reaction is not very different from that formed in the regular reaction, except the slightly lower ratio of C/S, which is the case for most of the pozzolans. The normal C/S ratio is believed to be around (ASTM, concrete and minerals admixture, 1972). The pozzolanic reaction in Eq. 2.1 and its kinetics are more similar to the slow rate of hydration of $C_2S$ [15]. Thus the addition of pozzolans has the similar effect of increasing the amount of $C_2S$. This results in the reduction of the rate of strength development and the heat of hydration, which makes it advantageous in mass concrete structures. The progress of hydration of cement can be measured by measuring the amount of Calcium hydroxide in the paste. Similarly, the extent of pozzolanic reaction can be followed by monitoring the decrease in calcium hydroxide over time. Figure 2.2 shows the relative amount of calcium hydroxide as the hydration time proceeds for different pozzolanic materials.

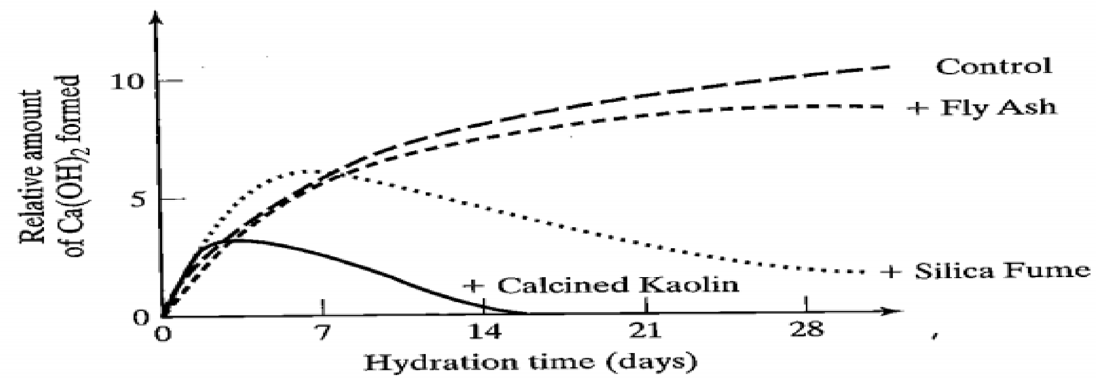



**Fig. 2.2. Comparison of the rate of reaction for various pozzolanic admixtures (Sidney Mindess., et al., 2003)**

To get the full benefit of pozzolanic materials prolonged moist curing of the concrete is required because of their slow reaction. Without this curing, the pozzolans simply act as non-cementitious fillers.

**2.4. Termite hill clay soil**

The consumption of supplementary cement replacing materials has become a new era for construction industry sectors. Out of this Blast furnace slag, silica fume, fly ash and rice husk can be sited as the example. Termite hill clay has also been found to have such pozzolanic property. Large termite hills, constructed by colonies of various species of *macro-termite* (Isoptera, Termitidae, and Macrotermitinae) are dominant features of the arid and semi-arid areas. These hills also populated a Southern most Borena lowland in very high densities. This termite builds the hill from clay materials necessary to uses in construction. The proportion of clay in termite hill is always higher than in the bulk soil, often highest in the royal cell and lowest in the outer wall (Turner, J.S., 2006). The loose soil that had been brought to the surface and piled on the ground by termites during an excavation of their nests weighed approximately 40 tons (Wirth, R., et al., 2013). Therefore a colony could approximately produce 40tons of soil. But they did not indicate how long it takes to make a colony. Termite clay is obtained from termite hill, while a hill is a pile of earth made by termite resembling a small hill. It is made of clay whose plasticity has further been improved by the secretion from the termite while using it in building the mound. The clay from the termite mound is capable of maintaining a permanent slope after molding because of its plasticity; it is also less prone to cracking when compared with ordinary clay (Mijinyawa Y. et al., 2007). Today, the high energy consumption by Portland cement industry causes environmental damage due to the release of high quantities of greenhouse gases.

Hence, several research activities are directed towards partial or full substitution of Portland cement with the pozzolanic binder in some applications. In recent years, the use of calcined clays as pozzolanic materials for mortar and concrete has received considerable attention. American Society for Testing and Materials (ASTM) set a minimum value of 70% for the sum of silica, alumina, and iron oxide of the total compounds making up the pozzolanic material with sulfur dioxide less than 4% and loss of ignition of less than 10% (Wafa M., et al., 2012). This interest is part of the widely spread attention directed towards the utilization of wastes and industrial by-products to minimize Portland cement consumption, the manufacture of which being environmentally damaging. Mortar and concrete, which contain pozzolanic materials, exhibit the considerable enhancement in durability properties (Chakchouk, A. et al., 2006). Portland cement production has been traditionally involved in calcination of limestone and siliceous clay to produce clinker, which is then undergrounded with 3-5% gypsum. However, current trends in cement production involve the addition of 5-70% mineral admixtures to improve the mechanical properties and durability of cement. According to Eugene *et al.,* 2014, the presence of admixtures like fly ash, limestone, slag and pozzolana in Portland cement influences the rate and degree of cement hydration as well as the phase composition of hydrated cement paste. In this research, termite clay powder will be used as a pozzolanic material to partially replace ordinary Portland cement. Pozzolans are natural rocks of volcanic origin and composed of silica and alumina oxides but almost no lime. Therefore, they cannot develop hydraulic properties in the absence of hydrated lime. Hydrated lime or material that can release it during its hydration (e.g., Portland cement) is then required to activate the natural pozzolana as a binding material. Reactive silica is readily dissolved in the matrix as $Ca\ (OH)_2$ becomes available during the hydration process. These pozzolanic reactions lead to the formation of additional Calcium silicate hydrates (C-S-H) with binding properties (Alp, I., et al., 2009). In Ethiopia, termite clay soil is available in many parts of the countries, but they are more prominent in arid and semi-arid areas. This makes it more viable for use as partial replacement for cement. Due to a lot of greenhouse gases emitted from the cement industry during cement production. Several types of research are directed towards partial or full substitution of Portland cement. In all these cases no research to the knowledge of the researcher has been done on the use of calcined termite clay soil. Therefore, this research was aimed to study chemical characteristics of activated termite hill clay soil, which has not been established in previous researches.

### 2.4.1 Pozzolanic property of Calcined termite hill clay powder

As described in previous sections pozzolans are siliceous or siliceous and aluminous materials which alone possess little or no cementitious value but which will, in finely divided form in the presence of moisture, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties (Moises, 2007).

Termite hill clay was also tested to have such property. It acts as a pozzolanic material when added to cement because of its silica ($SiO_2$) content which reacts with free lime released during the hydration of the cement and forms additional calcium silicate hydrate (CSH) as a new hydration product (Anigbogu, N.A., 2011).

This additional C-S-H improves the mechanical strength of the cement mortar and concrete. The research has assessed the pozzolanic effect of the calcined termite hill clay soils or in other word activated termite hill clay.

Therefore, the calcined termite hill has displayed the properties of the pozzolanic material that capable of replacing cement up to the certain percentage.

# CHAPTER THREE

# MATERIAL AND METHODS

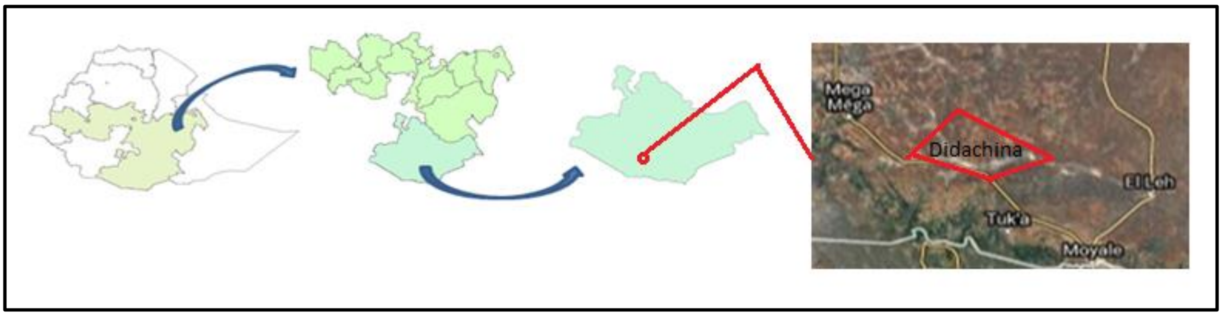
## 3.1. Introduction

In this chapter, the materials used for the research were described concerning their source. All the laboratory investigations on the aggregates, cement and grinding of calcined termite hill clay and concretes were carried out in JMC projects (India) limited Ethiopia branch, material quality control laboratory that found at Bokuluboma, which is around 727km from Addis Ababa towards the south. A JMC project is the foreign construction firms engaged in the construction of Mombasa -Nairobi- Addis Ababa road corridor phase -II, contracts Lot-III, Mega –Moyale road project. Whereas, calcination was done in Bule hora university chemistry laboratory and the chemical properties of the calcined termite hill clay powder were conducted in Geological survey laboratory of Ethiopia that found in Addis Ababa around Zambia Embassy residence.

## 3.2. Determining chemical properties of CTHCP used as partial replacement of cement in production of C-25 grade concrete

### 3.2.1. Calcined termite hill clay powder

The Termite hill clay powder was obtained from the southern part of Ethiopia, Oromia regional states, Borena Zone, Miyo Woreda, Bokuluboma town. Specifically, the termite hill clay powder was obtained from Didachina at the chain age of 240+270 LHS offset of 300m of the main highway from the Zonal capital Yabello to Kenya border as shown below on the map. In this part of the country, because of the arid and semi-arid nature of the environment, there were Termite hill clays abundantly.




*Ethiopian map* *Oromia map* *Borena zone*

**Fig. 3.1. Study area maps**

### 3.2.2. Cement

Dangote ordinary Portland cement (42.5N) used in this research was obtained from JMC project stock pile. This cement complies with the requirements of Standards, ASTM Standard. Designation: ASTM C 150/C 150M – 11.

### 3.2.3. Aggregates

The fine aggregate used was river sand obtained from Moyale sand quarry, at the chain age of 291+200 RHS offset of 3.5km from the main high way to Kenya border. It is free from deleterious matters. Laboratory tests were carried out to check the quality of the aggregate before taken to mix proportioning. And similarly, coarse aggregate used was obtained from JMC project crusher plant located at Bokuluboma site, 241+300 LHS (offset distance 2.0 Km). A maximum aggregate size of 19 mm was used in all the concrete tests. Materials were sampled purposively; purposive sampling is a method of non-probability sampling in which representative sample of the population was selected from a statistical population purposively with the predetermined probability of being selected.

### 3.2.4. Water

The water used for concreting was collected from bore well at Bokuluboma town at chain age of 241+300 LHS of the main highway to Kenya border from zonal capital Yabello. As per standard criteria, water used for concrete mixing should be potable drinking water.

### 3.2.5. Experimental setup

The Termite hill clay soil was collected once, after the outer part of the hill was removed up to 20cm to get weather undisturbed soil. Then, the sample was taken to Bule Hora University chemistry laboratory to calcine at the temperature of 650$^{o}$c, since best calcination temperature was between 600 $^{o}$c -800$^{o}$c using muffle furnace for an hour (Torres SM., 1999). And finally, it was allowed to cool for about 6hr before ground to the desired fineness using a manual grinder. Sieve analysis was carried out, and materials are passing sieve 150µm was used in this research. With the use of the manual grinder, obtaining samples less than 150µm was not possible. The powder is then taken to the Geological Survey laboratory of Ethiopia for the complete silicate analysis. Chemical characteristics of the CTHCP were determined using

Atomic Absorption Spectrophotometer (AAS), this is an analytical technique for characterizing materials.

The suitability of calcined termite hill clay powder was determined based on the concept of mineral admixtures in concrete (ASTM C618-98). The calcined termite hill clay powder was sieved through 200 micro sieves, and chemical composition of calcined termite hill clay powder was analyzed.

#### 3.2.5.1. Data collection procedure and analysis

The data required was obtained through laboratory experiments, the variables measured was chemical composition of CTHCP. Complete silicate analysis were done eleven chemical compounds were investigated with loss on ignition of the material. The laboratory experimental approach was used in this research. The data was analyzed using tables.

## 3.3. Determining the workability and compressive strength of concrete produced with calcined termite hill clay powder as partial replacement of cement.

### 3.3.1. Experimental setup

Different quality tests were made to identify the properties of the aggregates which used in this research work. Dangote Ordinary Portland cement fineness, consistency and setting time were determined in the laboratory with that of the blended pastes. Both fine and coarse aggregate were quartered before tests. Then, variables like sieve analysis and fineness modules, specific gravity and absorption capacity, moisture content, silt content and unit weight was determined. Additionally, water quality test was conducted at research, laboratory and training center of Ethiopian construction design and supervision corporation water quality section Addis Ababa. Finally, the design mix control mix of concrete was prepared to determine the unit weight of concrete cubes, workability and compressive strength of concrete produced with calcined termite hill clay powder as partial replacement of cement.

### 3.3.2. Data collection procedure and analysis

The required data was obtained through laboratory experiments, Consistency, setting time and fineness of OPC, gradation, specific gravity, unit weight, silt contents and natural moisture contents of the aggregates and pot ability of mix water. And finally, Unit weight, workability and compressive strength of concrete at both $7^{th}$ and $28^{th}$.The data were analyzed using the graphs and tables.

### 3.4. Investigating the optimal percentage of mix when calcined termite hill clay powder was partially replaced cement in production of grade C-25 concrete.

The optimal mix of the calcined termite hill clay powder for the replacement of cement is the percentage of replacement at which the compressive strength of the concrete cube is in the range of target mean strength of C-25 concrete grade.

#### 3.4.1. Experimental setup

The main objective of this research work was to study the suitability of calcined termite hill clay powder as partial cement replacing material in the production of C-25 grade concrete. These include studying properties of paste and concrete by replacing some parts of the cement with calcined termite hill clay powder in different percentages. Therefore, the experiment was made of concrete produced from cement partially replaced by calcined termite hill clay powder. These tests were used to determine the optimal mix of calcined termite hill clay powder, its effect on the performance of concrete such as workability and strength. Test program consists of preparing different concrete mixes with different percentage of calcined termite hill clay powder to study the performance of the concrete such as its workability and compressive.

The following replacement levels of Calcined termite hill clay powder of 0,5,10,15,20,25,30,35 and 40% for cement was used to determine the initial and final setting time, workability and compressive strength. The Standard BS 1881-116 prescribes a compressive strength test on concrete cube specimens. This procedure was adopted in preparing and testing samples for compressive strength and workability while viscat apparatus was used in measuring the setting time of the mix. The concrete was mixed in the concrete mixer at quality control laboratory. The slump for workability and cubes size of 150mmx150mmx150mm was used for compressive strength tests.

The specimens were demolded after 24 hours and then after cured in water tank having a temperature of $20^0$C. The compressive strength at both $7^{th}$ and $28^{th}$ day was checked using compressive strength testing machine.

**Table 3.1. Proportion of blending of calcined termite hill clay powder and cement**

| *S.№* | *Identity No.* | *Proportion of blend by weight* | |
|---|---|---|---|
| | | ***Dangote OPC (%)*** | ***Calcined termite hill clay powder (%)*** |
| *1* | *CTHCP-0* | *100* | *0* |
| *2* | *CTHCP-5* | *95* | *5* |
| *3* | *CTHCP-10* | *90* | *10* |
| *4* | *CTHCP-15* | *85* | *15* |
| *5* | *CTHCP-20* | *80* | *20* |
| *6* | *CTHCP-25* | *75* | *25* |
| *7* | *CTHCP-30* | *70* | *30* |
| *8* | *CTHCP-35* | *65* | *35* |
| *9* | *CTHCP-40* | *60* | *40* |

#### 3.4.1.1. Mix design

Mix design is the process of determining the required and specified characteristics of a concrete mixture. The required or specified concrete characteristics can be fresh concrete properties, mechanical properties of the hardened concrete such as strength and durability requirements and the inclusion or exclusion of specific ingredients (Biruk, 2011). Mix proportioning, on the other hand, is the process of determining the quantities of concrete ingredients using local materials to achieve the specified characteristics of the concrete. According to Steven H. (2003), a properly proportioned concrete mix should possess the following qualities:

- ✓ Acceptable workability of the freshly mixed concrete
- ✓ Durability, strength, and uniform appearance of the hardened concrete
- ✓ Economy

Therefore, the state of producing workable, strong and durable concrete depends on the careful proportioning and mix of the concrete ingredients.

ACI method of mix design was used in proportioning the mixes. The mix was prepared for characteristics strength of 25MPa with the target mean strength (TMS) of 34MPa, i.e., $TMS=f_c+S$, for compensation of uncertainty.

Where, *S*- standard deviation, *f*c- characteristic strength of concrete after required age. Meaning that, to have C-25 grade concrete the 28th day's compressive strength should be greater than 34MPa. The water to cement ratio, of 0.50 and a cement content of 360kg/m$^3$ [ACI-318 M Table-5.3.2.2**].**

The targeted slump was 25mm-75mm, and the control at the first trial mix has achieved it [ACI 211.1 Table A1. 5.3.1].The final mix proportions for 0.024m$^3$(it was designed for seven concrete cubes having 150mmx150mmx150mm dimensions) of the different control and Dangote OPC-CTHCP concretes are as shown in Table 3.2.

**Table 3.2. Mix proportion for the concrete cubes for compressive strength tests**

| *Mix codes* | *Cement type* | *Cement quantity (kg/m$^3$)* | *CTHCP (kg/m$^3$)* | *W/B ratio* | *Water (kg/m3)* | *FA (kg/m3)* | *CA (kg/m3)* |
|---|---|---|---|---|---|---|---|
| *CTHCP-0* | *Dangote OPC* | *360* | *0* | *0.5* | *180* | *809.66* | *1000* |
| *CTHCP-5* | *Dangote OPC* | *342* | *18* | *0.5* | *180* | *809.66* | *1000* |
| *CTHCP-10* | *Dangote OPC* | *324* | *36* | *0.5* | *180* | *809.66* | *1000* |
| *CTHCP-15* | *Dangote OPC* | *306* | *54* | *0.5* | *180* | *809.66* | *1000* |
| *CTHCP-20* | *Dangote OPC* | *288* | *72* | *0.5* | *180* | *809.66* | *1000* |
| *CTHCP-25* | *Dangote OPC* | *270* | *90* | *0.5* | *180* | *809.66* | *1000* |
| *CTHCP-30* | *Dangote OPC* | *252* | *108* | *0.5* | *180* | *809.66* | *1000* |
| *CTHCP-35* | *Dangote OPC* | *234* | *126* | *0.5* | *180* | *809.66* | *1000* |
| *CTHCP-40* | *Dangote OPC* | *216* | *144* | *0.5* | *180* | *809.66* | *1000* |

### 3.4.1.2. Preparation of concrete cubes specimen and mixing procedure

Batching of the concrete ingredient was made for preparation of the constituent. After determining the relative amount of materials to be used for the specimens, the aggregates, the cement, and calcined termite hill clay powder were mixed thoroughly in the dry state using the concrete mixer.

**Fig 3.2.Dry mixing of concrete ingredients**

Then water was added, all the materials were mixed till uniform mixture was formed with two minutes. Instantly, after the concrete was mixed the workability was measured by using a slump cone. The specimens were then placed on a firm and level surface of prepared molds (150mm x 150mm x 150mm) and have compacted in three layers using blowing rod 25 blows for each layer. After vibration, the top surface is finished using a trowel. After 24 hours the specimens were demolded from the mold and were cured in a curing pond up to its respective age ranges.

**Fig 3.3. Measure of Concrete workability using slump cone**

### 3.4.2. Data collection procedure and analysis

The data required was obtained through laboratory experiments, the variables measured were compressive strength, unit weight and workability of blended and normal concrete. The data was analyzed using graphs and tables.

#### 3.4.2.1. Compressive strength of concrete

The analysis of data collected was done in the following manner; the results from the compression test were in the form of maximum load the cube can carry before it ultimately fails. The compressive stress was obtained by dividing the maximum load by the area normal to it. $\delta = P/A$, (Equation 3.1.)

Where;

P- is the maximum load carried by the cube at failure.

A -is the area normal to the load

δ- is the maximum compressive stress ($N/mm^2$).

#### 3.4.2.2. Unit weight of concrete cube

The unit weight of the cube was determined by dividing the weight of concrete cube by volume of the cube after every respective curing age. The volume of cube is (150mmx150mmx150mm), while its weight was determined by beam balance.

Density = Mass/Volume… (Equation 3.2.)

### 3.5. Population

As the research population, the sample of Termite hill clay was collected from Bokuluboma vicinity specifically, Didachina where is the home of this material.

### 3.6. Sampling procedure

From non-probability sampling, purposive sampling was done for the collection of data from the sample area, since the area was purposively selected due to the availability of the material that has been researched.

### 3.7. Study Variables

### 3.7.1. Independent Variables

The independent variables which has been measured and manipulated to determine its relationship to observed phenomena are listed below.

- ✓ Consistency of OPC cement
- ✓ setting time of OPC cement
- ✓ Fineness of OPC cement
- ✓ Chemical composition of CTHCP
- ✓ Gradation,
- ✓ absorption
- ✓ specific gravity of the aggregates
- ✓ replacement percentages

### 3.7.2. Dependent variables

The dependent variable which was observed and measured to determine the effect of the independent variables is:

- ✓ Consistency of blended pastes
- ✓ Setting time of blended pastes
- ✓ Workability
- ✓ unit weight of the concrete
- ✓ Compressive strength of the concrete.

### 3.8. Data Analysis and presentation

Research Data was analyzed using spreadsheets software. And it was presented in form of graph and tables for illustration of the results. Tabulation of set standard criteria was also done for examination of the effect easily.

The following conceptual framework was followed to reach the finding of the research.

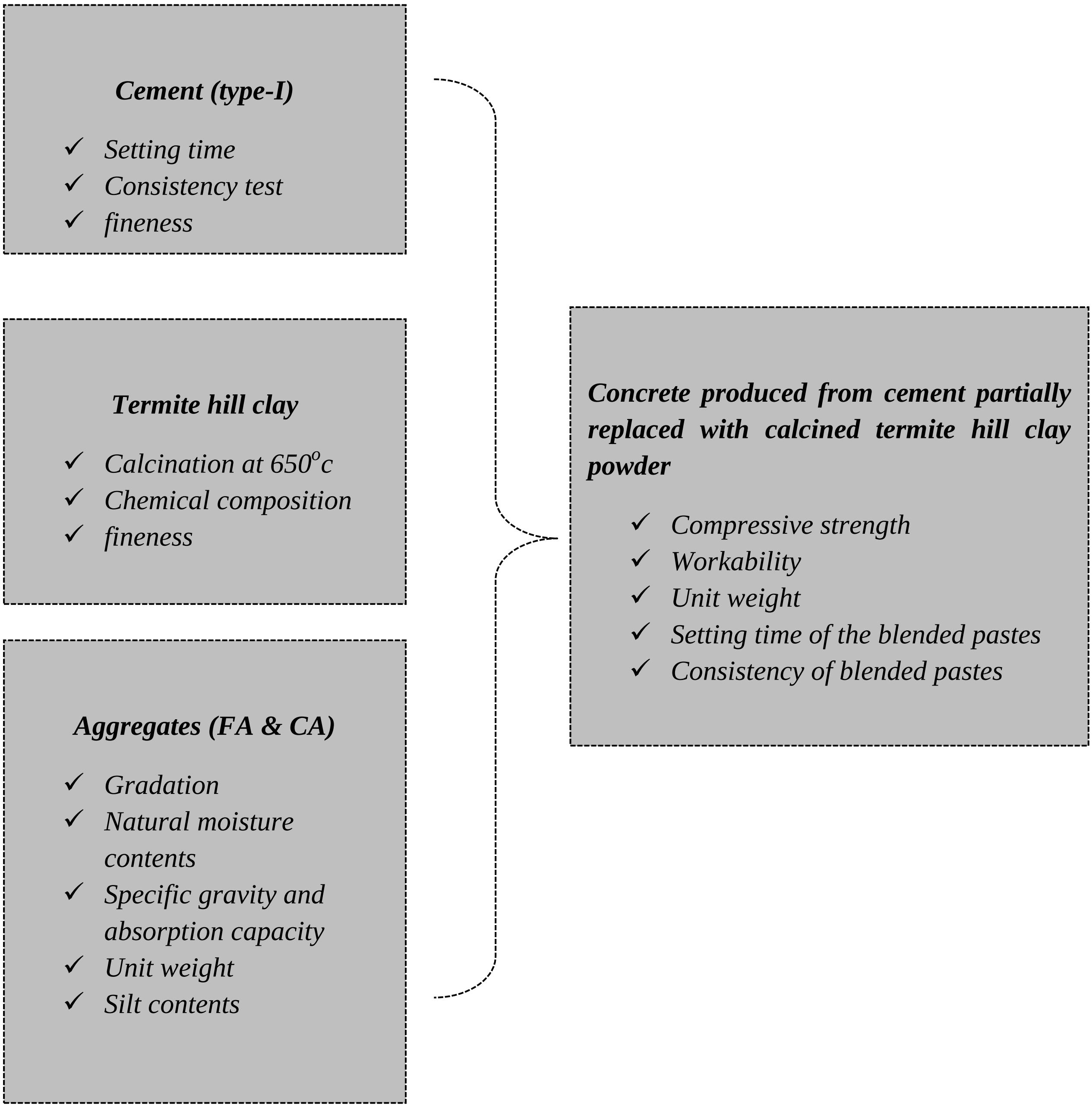



**Fig.3.4. Conceptual framework**

# CHAPTER FOUR

# RESULTS AND DISCUSSION

## 4.1. Introduction

In this chapter discussion and analysis of laboratory experiments results of calcined termite hill clay powder for its suitability as cement replacing material were analyzed and presented.

- ✓ Aggregates quality tests that used in the preparation of control and blended mix of this research work.
- ✓ The fineness for different replacement of cement with calcined termite hill clay powder
- ✓ The chemical composition of calcined termite hill clay powder used as cement replacement
- ✓ The consistency and setting time of the blended pastes at different replacement contents
- ✓ Compressive Strength of concrete containing calcined termite hill clay powder which partially replaces ordinary Portland cement
- ✓ The workability and unit weight of concrete containing calcined termite hill clay powder at different replacements percentages

## 4.2. Chemical composition of CTHCP used as partial replacement of cement in production of C-25 grade concrete

Under this section test results on the chemical properties of calcined termite hill clay powder was analyzed and discussed.

### 4.2.1. Chemical composition of calcined termite hill clay powder

Chemical analysis of CTHCP was carried out using Atomic Absorption Spectrophotometry (AAS); this is an analytical technique for characterizing materials.

**Table 4.1. Chemical composition of Calcined termite hill clay powder**

| S. № | *Chemical Composition* | *Quantity in percentages* |
|---|---|---|
| 1 | $SiO_2$ | *38.82* |
| 2 | $Al_2O_3$ | *23.98* |
| 3 | $Fe_2O_3$ | *11.68* |
| 4 | *CaO* | *19.22* |
| 5 | *MgO* | *12.64* |
| 6 | $Na_2O$ | *0.24* |
| 7 | $K_2O$ | *0.28* |
| 8 | *MnO* | *0.01* |
| 9 | $TiO_2$ | *0.05* |
| 10 | $P_2O_5$ | *0.16* |
| 11 | $H_2O$ | *0.77* |
| 12 | *LOI* | *21.06* |

As shown in Table 4.1, the main components of CTHCP are $SiO_2$ (38.82%), $Fe_2O_3$ (11.68%), ($Al_2O_3$ 23.98%). The sum of $SiO_2$, $Fe_2O_3$ and $Al_2O_3$ also exceeded the minimum limit of 70% (i.e. $SiO_2 + Al_2O_3 + Fe_2O_3 = 74.48 > 70\%$) prescribed by ASTM C 618 for the Pozzolana samples. Therefore, the material was found to be chemically suitable as a pozzolanic material of Class N Pozzolana and can be used to partially replace cement. The loss on ignition (LOI) value for the calcined termite hill clay powder was found to be 21.06 which is higher than that specified by the ASTM standard (10%). The sulfur trioxide amount was found negligible value (i.e. far less than zero) and discarded from the table during the analysis. The ASTM recommends value less than 4%.Moreover, the calcined termite hill clay powder was found to have almost less alkali content like $K_2O$ (0.28%) implying less contribution for the alkali-silica reaction when used in concrete with active aggregates. The summation of oxides: silica, alumina, and iron were found to be greater than the seventy percent (70%). This implies that, as indicated above under the table, calcined termite hill clay powder can be classified as class N Pozzolana.

### 4.3. Workability and compressive strength of concrete produced with calcined termite hill clay powder as partial replacement of cement.

The workability and strength of the concrete depends on the quality of concrete making materials. These quality tests of ingredients (i.e. quality binding material, aggregates and mixing water) were investigated and presented as follow.

#### 4.3.1. Fineness of Dangote ordinary Portland cement and CTHCP

The fineness of the calcined termite hill clay powder and the cement were determined by the blain air permeability method. ASTM C 150 recommends test method of (ASTM C 204) for fineness by air permeability. The fineness of both cement and calcined termite hill clay powder was as shown below.

**Table 4.2. The fineness of cement and calcined termite hill clay powder.**

| S. № | Material | Fineness ($m^2$/kg) |
|---|---|---|
| 1. | Dangote ordinary Portland cement | 334.4 |
| 2. | Calcined termite hill clay powder (CTHCP) | 293.1 |

As shown in Table 4.2. Calcined termite hill clay powder has the lower surface area (Blaine surface area, 293.4 $m^2$/kg) as compared to Dangote OPC. According to the Ethiopian standard ordinary Portland cement shall have a specific surface area of not less than 225 $m^2$/kg , whereas the ASTM C 204 standard recommends a minimum of 260 $m^2$/Kg. with no maximum value. Therefore, both cement and calcined termite hill clay powder was complied with the ASTM C 204 requirement for the fineness.

#### 4.3.2. Normal consistency

According to ASTM C 595 recommendation the normal consistency tests of blended cement to be measured by the ASTM C 187 method, which is the method similar with that of hydraulic cement. Therefore, the normal consistency was measured by a Vicat apparatus. This measure the resistance of the paste to the penetration of a plunger or needle of 300gm released at the surface of the paste.

The procedure used for this test is as described in ASTM C 187. Different pastes both control, i.e., without calcined termite hill clay powder (0% replacement) and blended were prepared by replacing part of the Dangote ordinary Portland cement with calcined termite hill clay powder. The water content was varied for each of the pastes produced until a normal consistent paste is obtained. The replacements were from 0% to 40% with 5% increasing intervals.

**Table 4.3. Normal consistency of blended paste containing CTHCP**

| S. № | Mix codes | Consistency (%) |
|---|---|---|
| 1 | *CTHCP-0* | 25 |
| 2 | *CTHCP-5* | 25 |
| 3 | *CTHCP-10* | 25.5 |
| 4 | *CTHCP-15* | 26 |
| 5 | *CTHCP-20* | 26.7 |
| 6 | *CTHCP-25* | 27 |
| 7 | *CTHCP-30* | 27.4 |
| 8 | *CTHCP-35* | 28 |
| 9 | *CTHCP-40* | 28.6 |

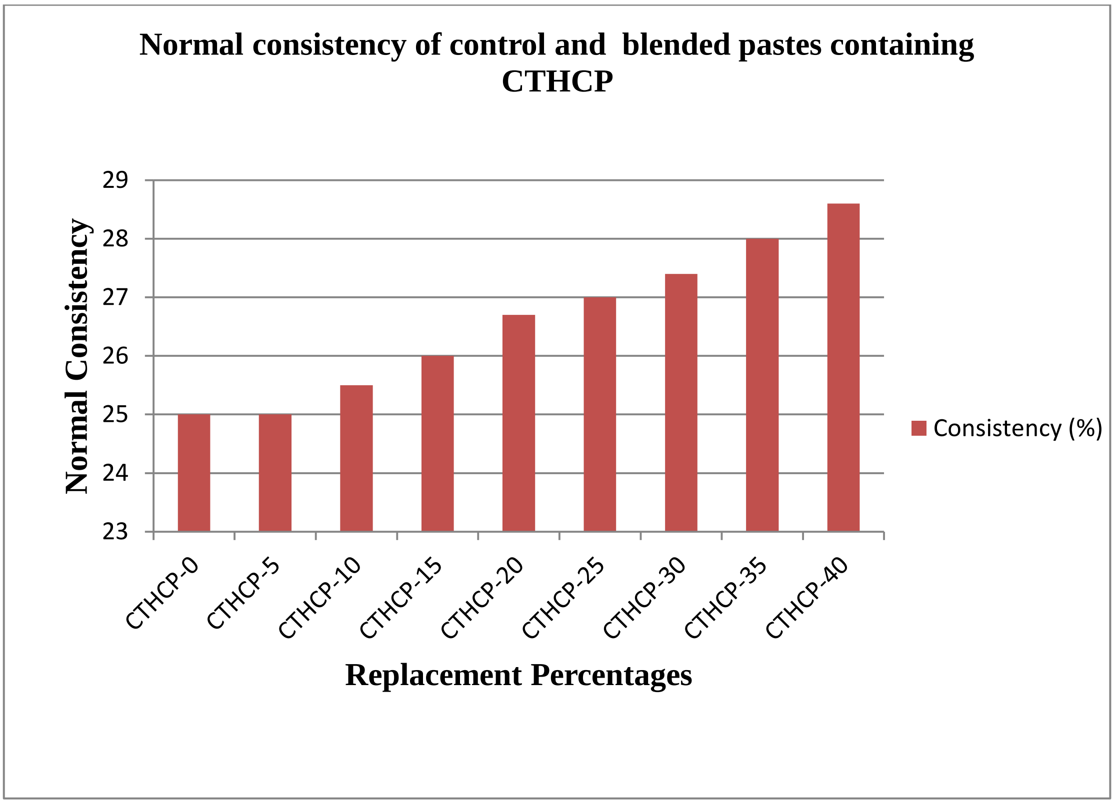



**Fig. 4.1. Normal consistency of control and blended pastes**

The experimental results on the consistency of Table 4.3 Showed that the blended pastes containing calcined termite hill clay powder need more water than that of control paste which is 25%. The percentage increase in water requirement of this blended paste is probably due to the higher porosity of calcined termite hill clay powder as compared to cement. The usual range of water to cement ratio for normal consistency is between 25% and 33% (Abebe Dinku, 2002). The pastes with replacement up to 10% showed a consistency very close to that of the control paste, however, after 10% replacement the results showed slightly higher values, even though it is within the standard ranges.

### 4.3.3. Setting time of control and blended paste

ASTM C 595 recommends the use of ASTM C 191 method of measuring setting time, which is used for that of hydraulic cement. The initial setting time of the paste was determined by the duration of 25mm penetration of Vicat needle into the paste in 30 seconds after it has been released while the final setting time was determined by measuring the time related to zero penetration of the needle into the paste.

**Table 4.4. Setting time of control and blended paste containing CTHCP**

| S. № | Mix codes | Setting time (min.) | |
|---|---|---|---|
| | | **Initial setting time** | **Final setting time** |
| 1 | *CTHCP-0* | 151 | 267 |
| 2 | *CTHCP-5* | 147 | 262 |
| 3 | *CTHCP-10* | 143 | 250 |
| 4 | *CTHCP-15* | 138 | 241 |
| 5 | *CTHCP-20* | 131 | 232 |
| 6 | *CTHCP-25* | 128 | 227 |
| 7 | *CTHCP-30* | 126 | 222 |
| 8 | *CTHCP-35* | 124 | 217 |
| 9 | *CTHCP-40* | 123 | 210 |

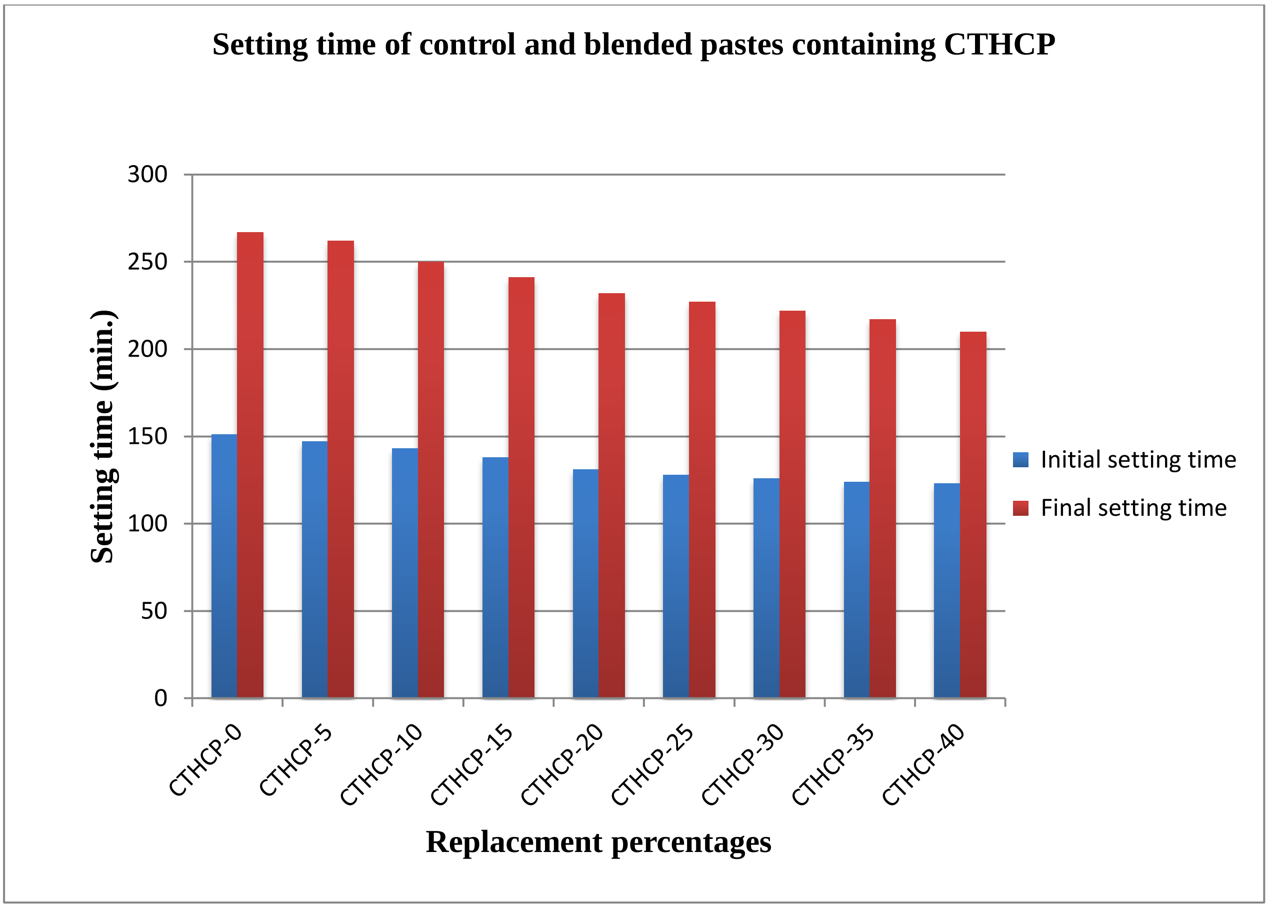



**Fig. 4.2. Setting time of control and blended pastes**

As is indicated in Table 4.4 above, the addition of calcined termite hill clay powder accelerates the initial and final setting time of the pastes. The ASTM C191 standard limits the initial setting time of hydraulic cement not to be less than 45 minutes and the final setting time not to exceed 375min. As the calcined termite hill clay powder content increases, the setting time has also shown a trend of decrements despite some laboratory uncertainty. The researcher called A.U.Elinwa, (2005) had also confirmed to the decrease in setting time of cement-calcined termite hill clay powder blended pastes of similar supplementary cementitious materials. The Calcined termite hill clay powder particles here act as sites of nucleation and have prompted the hydration mechanism to speed up. The setting of cement paste is recognized to be caused by the increasing volume of hydration products and leads to a decrease in the distance between individual particles until the plastic flow is restricted by cohesive forces (Wang L., et al., 2001).

### 4.3.4. Properties of Fine Aggregate

These include sieve analysis and fineness modulus, specific gravity and absorption capacity, moisture content, silt content and unit weight.

#### 4.3.4.1. Silt contents

The material in fine aggregates which is finer than 75µm is regarded as silt. This silt in the sand for the concrete has a severe effect on the quality of the concrete. It mainly affects the workability of the concrete, and also results in the reduction of strength.

**Table 4.5. Results of Silt content for Moyale river sand**

| *Trial No* | *Weight. Before washing (g)* | *Weigh. After washing (g)* | *Silt Content (g)* | *silt Content (%age)* | *Average .silt Content (%)* |
|---|---|---|---|---|---|
| 1 | 1109.0 | 1105.1 | 3.90 | 0.35 | 0.35 |
| 2 | 1057.0 | 1053.3 | 3.70 | 0.35 | |

From the silt content test performed on the sand as per AASHTO T-11, it was found that the original silt content was 0.35% (Table 4.5.). The Ethiopian standard restricts the salt content to a maximum of 6%. Therefore, the silt content of the sand was within the specification range.

#### 4.3.4.2. Sieve Analysis and fineness modules

This is a procedure for the determination of the particle size distribution of the aggregate. It is also used to determine the fineness modulus, an index to the fineness, coarseness, and uniformity of aggregates. These properties of the aggregate greatly affect the property of the concrete. The grading is determined in accordance with ASTM C 136, "Sieve or Screen Analysis of Fine and Coarse Aggregates.

**Table 4.6. Sieve analysis results and standard specification for fine aggregates**

| *Sieve Designation (mm)* | *Mass Retained (g)* | *%age Retained* | *%age Passing* | *Specification Limit* | |
|---|---|---|---|---|---|
| 9.5 | 0.0 | 0.0 | 100.0 | 100 | 100 |
| 4.75 | 42.5 | 4.0 | 96.0 | 95 | 100 |

| | | | | | |
|---|---|---|---|---|---|
| 2.36 | 225.3 | 21.3 | 74.7 | 68 | 86 |
| 1.18 | 246.9 | 23.4 | 51.3 | 47 | 65 |
| 0.6 | 165.7 | 15.7 | 35.6 | 27 | 42 |
| 0.3 | 221.5 | 21.0 | 14.7 | 9 | 20 |
| 0.15 | 133.5 | 12.6 | 2.0 | 0 | 7 |
| 0.075 | 13.0 | 1.2 | 0.8 | 0 | 2.5 |
| Pan | 8.6 | 0.8 | 0.0 | | |

According to ASTM C 136 to have fine quality aggregates the gradation of the aggregate should not be out of the lower and upper limit set. From Table 4.6. The gradation of Moyale sand was within the specification range. Therefore, the sample sand used in this research was met the grading requirement (ASTM 136) and used for the mix directly. The fineness modulus of the sand was 3.26 in the range of ASTM 136 which is between 2 -3.3.And the sand classified as coarse sand. The graph for the sieve analysis of the sand and the standard is as follows.

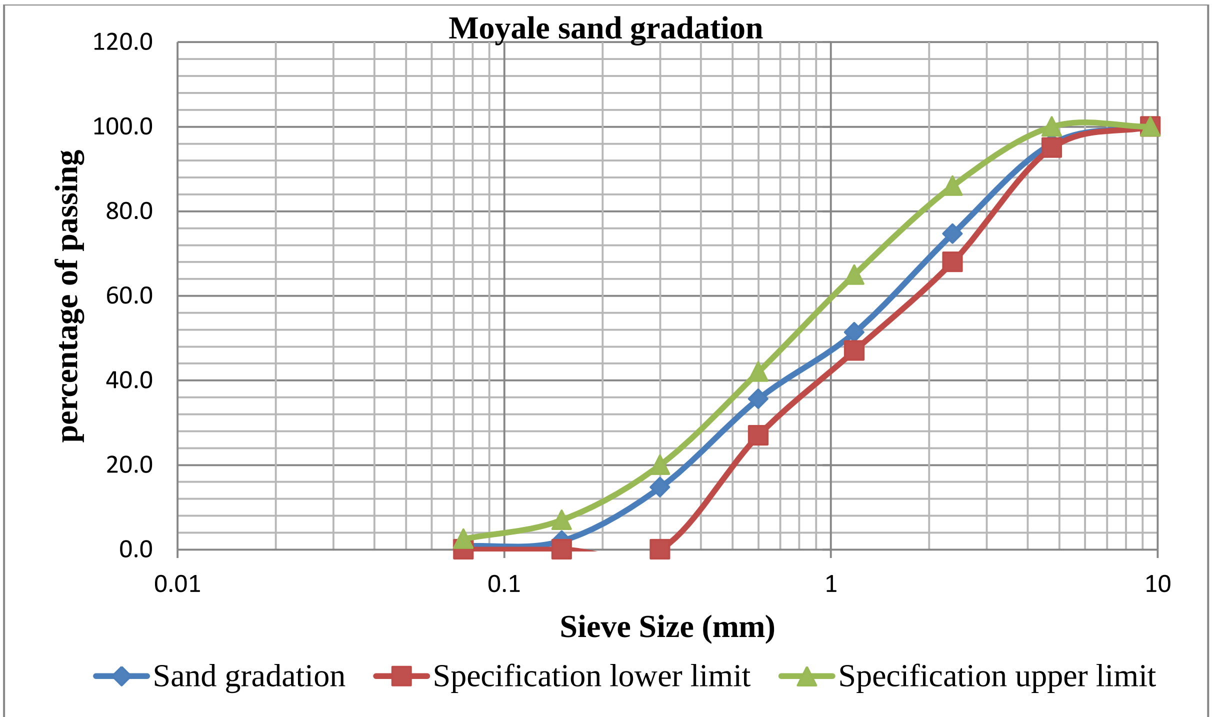



**Fig. 4.3. Gradation curve of fine aggregate**

Fineness Modules = ∑cumulative coarser (%)/100 = 3.26

#### 4.3.4.3. Specific gravity and Absorption capacity

Specific gravity is an expression of the density of an aggregate. It is the ratio between the weight of the substance and that of the same volume of water. Aggregates contain pores in their structure, Therefore the specific gravity depends on whether the pores are included in the measurement or not. The apparent specific gravity of an aggregate refers to the solid materials excluding the pores, and bulk specific gravity refers to total volume, i.e., including pores of the aggregate. The entire data was attached to the appendix.

The following results are found for the fine aggregate:

- ✓ Bulk specific gravity = 2.650
- ✓ Bulk specific gravity (SSD basis) = 2.677 As per ASTM C 33 specification 2.30-2.90
- ✓ Apparent specific gravity = 2.725
- ✓ Absorption capacity = 1.052 , As per ASTM C 33 specification 0-4%

**Fig 4.4. Determination of specific gravity of Moyale river sand**

#### 4.3.4.4. Natural Moisture content

The natural moisture contents of the aggregates largely affect water to cement ratio of concrete. On the other hand, excess in the mix also affects the strength and the workability of the concrete.

Meaning, that, increase in water-cement ratio results in a decrease of the strength of the concrete and an increase of workability. The aggregates in concrete are assumed to be inert materials. But most of the aggregates do not meet this assumption by either absorbing water (dry aggregates) or by releasing it (wet aggregates) to the mix. As a result of this property of aggregates the design water to cement ratio of the mix changes. Therefore, it is important to determine both the absorption capacity and the moisture content of the aggregate. The moisture content of fine aggregates was determined by directly burning the aggregates on the stove and checked for the significant weight difference [Appendix]. The natural moisture content of the river sand found was 1.245 %.

**Fig 4.5. Natural moisture contents determination**

### 4.3.4.5. Unit weight

Unit weight can be defined as the weight of a given volume of graded aggregate. It is thus a density measurement and is also known as bulk density. But this alternative term is similar to bulk specific gravity, which is quite a different quantity, and perhaps is not a good choice. The unit weight effectively measures the volume that the graded aggregate will occupy in concrete and includes both the solid aggregate particles and the voids between them. The unit weight is simply measured by filling a container of known volume and weighing it. However, the degree of compaction will change the amount of void space, and hence the value of the unit weight. Since the weight of the aggregate is dependent on the moisture content of the aggregate, constant moisture content is required. Oven dried aggregate sample is used in this test. The unit weight of the fine aggregate sample used was found to be 1.425 g/cm$^3$. The entire fine aggregates quality tests were summarized below.

**Table 4.7. Summary of test results for fine aggregate**

| ***Serial number*** | ***Tests description*** | | ***Results*** |
|---|---|---|---|
| 1 | Silt contents | | 0.35% |
| 2 | Natural moisture contents (NMC) | | 1.245% |
| 3 | Unit weights | | 1.425g/cm$^3$ |
| 4 | Water absorption capacity | | 1.052% |
| 5 | Specific gravity | Bulk (SSD) | 2.677 |
| | | Bulk | 2.650 |
| | | Apparent | 2.725 |
| 6 | Fineness modulus | | 3.20 |

As shown in the summary table 4.7. Of fine aggregate quality tests, unit weight, natural moisture contents, specific gravity (i.e., saturated surface dry) and water absorption was 1.425 g/cm$^{3,}$ 1.245%, 2.677, and 1.052% respectively. From this result the natural moisture contents of the fine aggregate are 1.245%, this implies that the aggregate has absorbed the water from the field. (According to ASTM 136 the absorption capacity of the aggregates should be within 0.5%-4%), therefore the absorption is within specification range. Thus, the aggregate was adjusted for both NMC and an absorption capacity in the mix, as it does not affect the anticipated compressive strength. Because it is obvious that water-cement ratio seriously affects the strength of concrete. Whereas, the density of the aggregate and specific gravity is required in mix proportioning to establish weight-volume relationships during batching of materials. The aggregate was calibrated for these parameters before used in the production of concrete.

### 4.3.5. Properties of Coarse Aggregates

After washing and drying, the coarse aggregates were sieved and stored. This has minimized segregation and thus variation in gradation from mix to mix. Like fine aggregates, laboratory tests were carried out to identify the physical properties of the coarse aggregate. These laboratory tests were: sieve analysis and fineness modulus, specific gravity and absorption capacity, moisture content, silt content and loose and dry unit weight of the aggregates. The entire tests data were attached to the appendix of this manuscript. But, here is the summary of coarse aggregates conducted laboratory quality tests below.

**Table 4.8. Summary of test results for coarse aggregates**

| *Serial number* | *Tests description* | | *Results* |
|---|---|---|---|
| 1 | Maximum aggregate size | | 19mm |
| 2 | Natural moisture contents (NMC) | | 0.194 |
| 3 | Dry rodded Unit weights | | 1.590/cm$^3$ |
| 4 | Loose unit weights | | 1.475 g/cm$^3$ |
| 5 | Water absorption capacity | | 0.49% |
| 6 | Specific gravity | Bulk (SSD) | 2.652 |
| | | Bulk | 2.64 |
| | | Apparent | 2.674 |

ASTM C 33 ("Standard Specifications for Concrete Aggregates") limits the range of physical properties of normal weight aggregates. Nominal maximum size 9.5mm-37.5mm, absorption 0.5%-4%, bulk specific gravity 2.30-2.90, dry rodded bulk unit weight, 1280kg/m3-1920kg/m3 and moisture contents 0-2%. The above all results were found to be with the standard limits.

**Table 4.9. Sieve analysis for coarse aggregate**

| *Sieve Designation (mm)* | *Mass Retained (g)* | *%age Retained* | *%age Passing* | *Specification Limit* | |
|---|---|---|---|---|---|
| 25 | 0.0 | 0.0 | 100.0 | 100 | 100 |
| 19 | 729.0 | 5.8 | 94.2 | 80 | 100 |
| 10 | 8195.0 | 65.0 | 29.2 | 10 | 40 |
| 4.75 | 3298.0 | 26.2 | 3.1 | 0 | 4 |
| 0.075 | 310.0 | 2.5 | 0.6 | 0 | 0.5 |

From Table 4.9. Above the sieve analysis of coarse aggregates was done as per AASHTO T-27. The percentage of passing for entire sieves was cross-checked with the specification limit set by AASHTO. And it was found that the finer percentage lies between, the lower and upper limit. This implies that coarse aggregate used in the concrete production have the grading requirements of the standard. Therefore, the use of this crushed aggregate has improved the packing density, workability of the concrete, minimizes the paste requirements then cements contents and finally, minimizes the segregation problem.

Also, the gradation curve below was S-shaped graph lies between the lower and upper specification limit.

**Fig 4.6. Coarse aggregate gradation**

The gradation curve for the sieve analysis of the coarse aggregate and the standard (AASHTO T-27) is as shown in Figure 3.4 below.

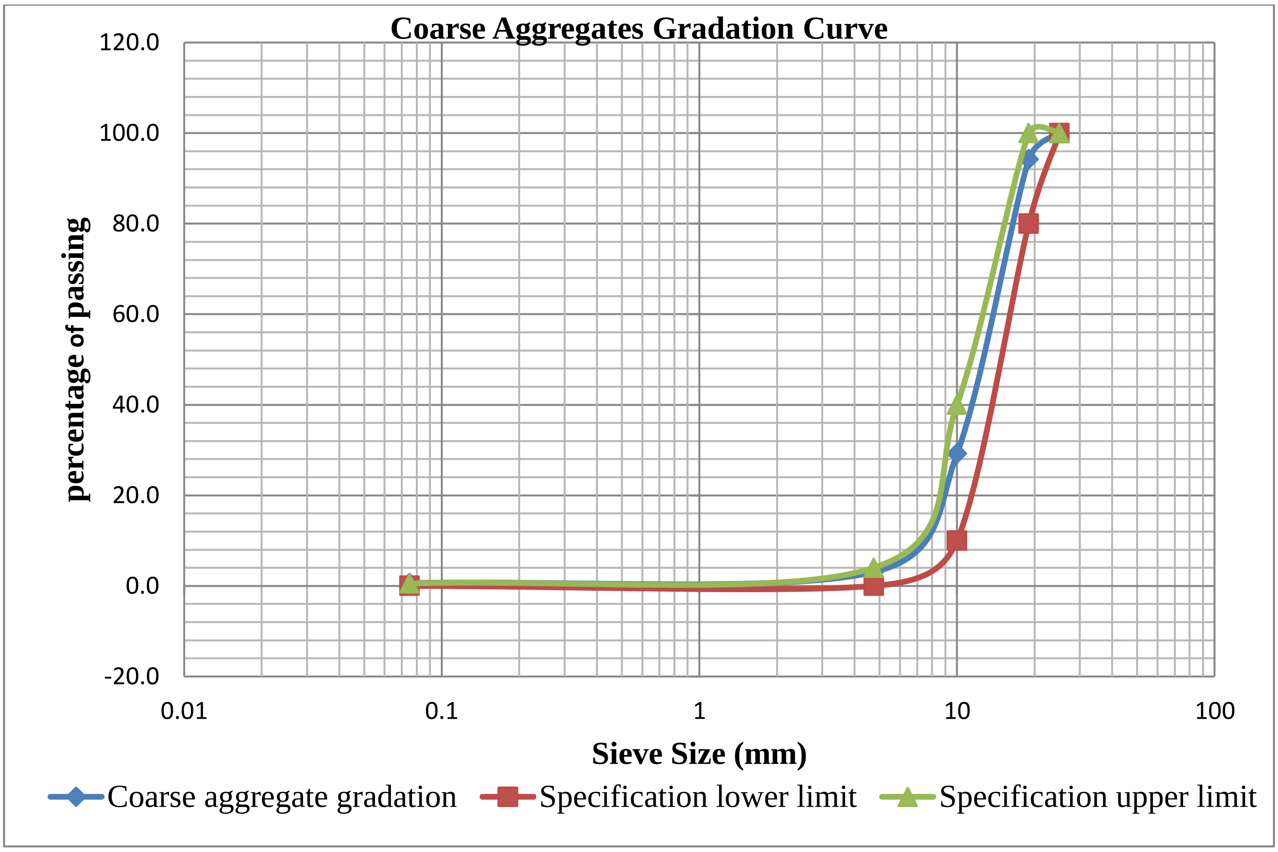



**Fig. 4.7. Gradation curve of coarse aggregate**

**Table 4.10. Water quality tests of bore well at Bokuluboma**

| ***Test conducted*** | ***Results obtained*** | | ***WHO maximum allowable concentration mg/l*** |
|---|---|---|---|
| | ***Sample-1*** | ***Sample-2*** | |
| PH | 7.40 | 7.41 | 6.5-8.5 |
| Electrical conductivity (μS/cm) | 784.00 | 715.00 | - |
| Dissolved solids $105^{o}$c (mg/l) | 522.00 | 474.00 | 1000.0 |
| Alkalinity (mg/l $CaCO_3$) | 237.50 | 212.80 | - |
| Carbonates (mg/l $CO_3^{2-}$) | Nil | Nil | - |
| Bi carbonate (mg/l $HCO_3^{2-}$) | 289.75 | 259.62 | - |
| Chloride (mg/l $Cl^-$) | 86.53 | 77.18 | 250.0 |
| Sulphate (mg/l $SO^{2-}{}_4$) | 52.88 | 53.81 | 400.0 |

The water used for mixing was from bore well at Bokuluboma. In the case of doubt about the suitability of water particularly in remote areas, where water is derived from sources of normally utilized for the domestic purpose, water should be tested (M.L. Gambhir, 2002). As shown in the table 4.10. Above dissolved solid and chemical compound was analyzed. To the extent, those chemicals were compared with the world health organization thresholds to judges the pot ability of the water for drinking since the water safe for the drink is safe for concrete mix. ASTM C 1602-06 limits the impurities in the mix water for chlorides, sulfates and alkali. For chloride ions 1000mg/l, sulfate ion 3000mg/l and 600mg/l for alkalinity. From the table concentration value of chloride, sulfate and alkalinity were less than that of standard for both samples. This indicates that the water has no much effect on the concrete (i.e., setting time and strength). There is no significant objectionable stain, or unsightly deposit appeared on the surface of concrete cubes since water used for curing was also potable.

### 4.3.6. Fresh concrete

To assess the workability of the fresh concrete, the slump test was conducted. Slump test is the most commonly used method of measuring the consistency of concrete which can be employed either in the laboratory or at the site of work. It is not a suitable method for very wet or very dry concrete. It does not measure all factors contributing to workability, nor is it always representative of the place ability of the concrete.

The absence of other testing machine in the laboratory had forced the researcher to use slump cone for workability measurements. A concrete mix should be workable enough to be placed, compacted and finished. The ingredients in concrete should be in such a proportion as to allow a good workability of the concrete and sufficient strength to support the required load after hardening.

The trail mix for the control concrete gave a slump of 35mm, which is the range of targeted slump, i.e., 25-75mm [ACI 2111.1].
Therefore, no adjustment was made on the water-cement ratio. Table 4.11. Below gives the slump for all cement replaced by calcined termite hill clay powder in the concrete mixes:

**Table 4.11. Slump test results of concrete produced from cement replaced by CTHCP**

| *S.№* | *Identity No.* | *Replacement (%)* | *Water-binder ratio* | *Observed slump (mm)* |
|---|---|---|---|---|
| *1* | *CTHCP-0* | *0* | *0.5* | *35* |
| *2* | *CTHCP-5* | *5* | *0.52* | *35* |
| *3* | *CTHCP-10* | *10* | *0.55* | *29* |
| *4* | *CTHCP-15* | *15* | *0.58* | *28* |
| *5* | *CTHCP-20* | *20* | *0.62* | *26* |
| *6* | *CTHCP-25* | *25* | *0.66* | *25* |
| *7* | *CTHCP-30* | *30* | *0.71* | *23* |
| *8* | *CTHCP-35* | *35* | *0.77* | *22.3* |
| *9* | *CTHCP-40* | *40* | *0.83* | *21* |

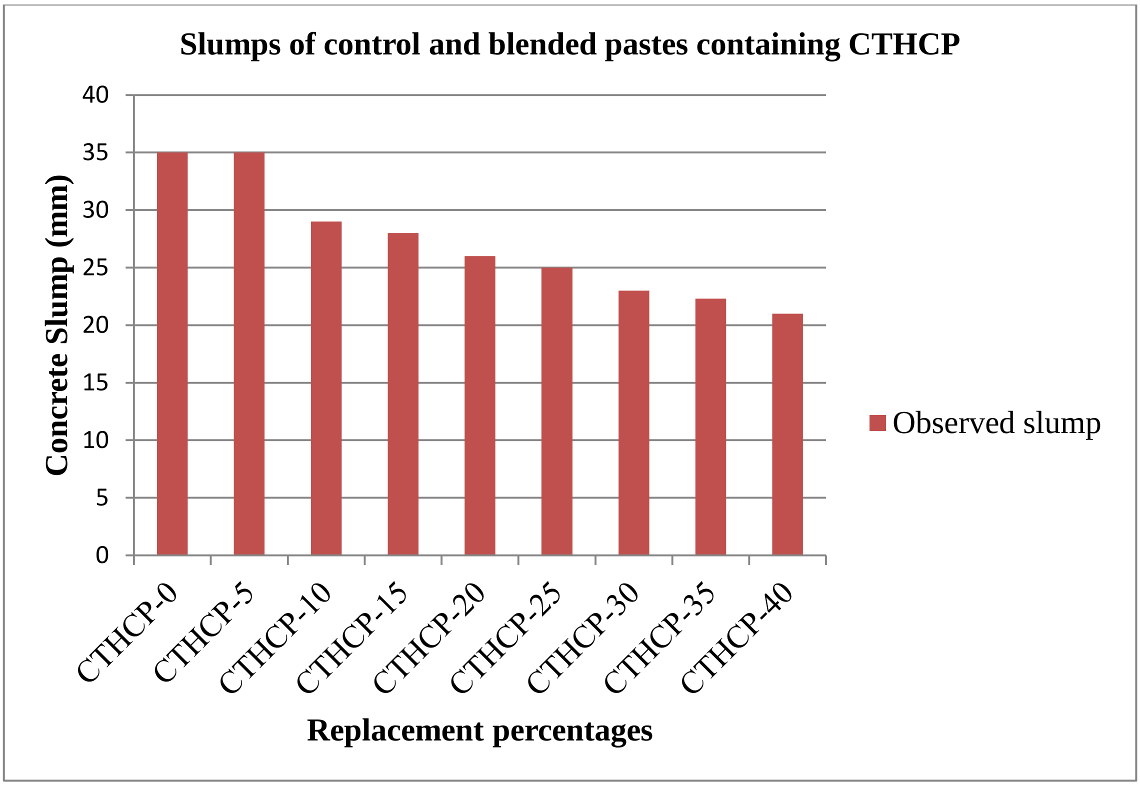



**Fig. 4.8. Slump of control and blended pastes**

From Table 4.11. The slumps of the concrete containing calcined termite hill clay powder have shown a moderate reduction as the CTHCP content increases When calcined termite hill clay powder contents reach 30% of replacements the slumps has started to be out the range fixed by targeted slump which is 25mm-75mm as shown above. Table 4.3 (normal consistency ), shows that the normal consistency of the blended pastes increased with increase of the calcined termite hill clay powder, this can also be an indication that in order to get a certain slump, Dangote ordinary Portland cement-CTHCP blended concretes needs a higher water content than a concrete with no calcined termite hill clay powder.

The probable reason is the lower density of CTHCP giving it a higher porosity, resulting in higher water demand. To get similar slump for the control and blended paste containing CTHCP concrete, the water content can be increased as the calcined termite hill clay powder content increases.

### 4.3.7. Hardened concrete

Similar to fresh concrete properties there are hardened properties that affect the long range performance of the concrete. In this section hardened properties like the unit weight of concrete cubes and compressive strength are analyzed and presented as below.

**Fig.4.9. Steps in cube tests from left to right: greasing of mold, casting, curing and crushing**

#### 4.3.7.1 Unit weight

Since the volume of the cubes molds was already known (i.e., 150mmx150mmx150mm), the weight of concrete cubes were measured just before crushing the sample. These tests were conducted at 7 and 28 days. The entire results for the weight and dimension were attached to the appendix. In this case, the unit weight of concrete cubes was calculated at both cube ages, and the results were shown below.

**Table 4.12. Unit weights of concrete cubes with CTHCP replacing percentages 7$^{th}$ day**

| *S.№* | *Identity No.* | *Replacement (%)* | *Unit weights (g/cm$^3$)* | *Unit weight reduction (%)* |
|---|---|---|---|---|
| *1* | *CTHCP-0* | *0* | *2.64* | *0* |
| *2* | *CTHCP-5* | *5* | *2.621* | *0.019* |
| *3* | *CTHCP-10* | *10* | *2.595* | *0.026* |
| *4* | *CTHCP-15* | *15* | *2.583* | *0.012* |
| *5* | *CTHCP-20* | *20* | *2.58* | *0.003* |
| *6* | *CTHCP-25* | *25* | *2.578* | *0.002* |
| *7* | *CTHCP-30* | *30* | *2.576* | *0.002* |
| *8* | *CTHCP-35* | *35* | *2.465* | *0.111* |
| *9* | *CTHCP-40* | *40* | *2.439* | *0.026* |

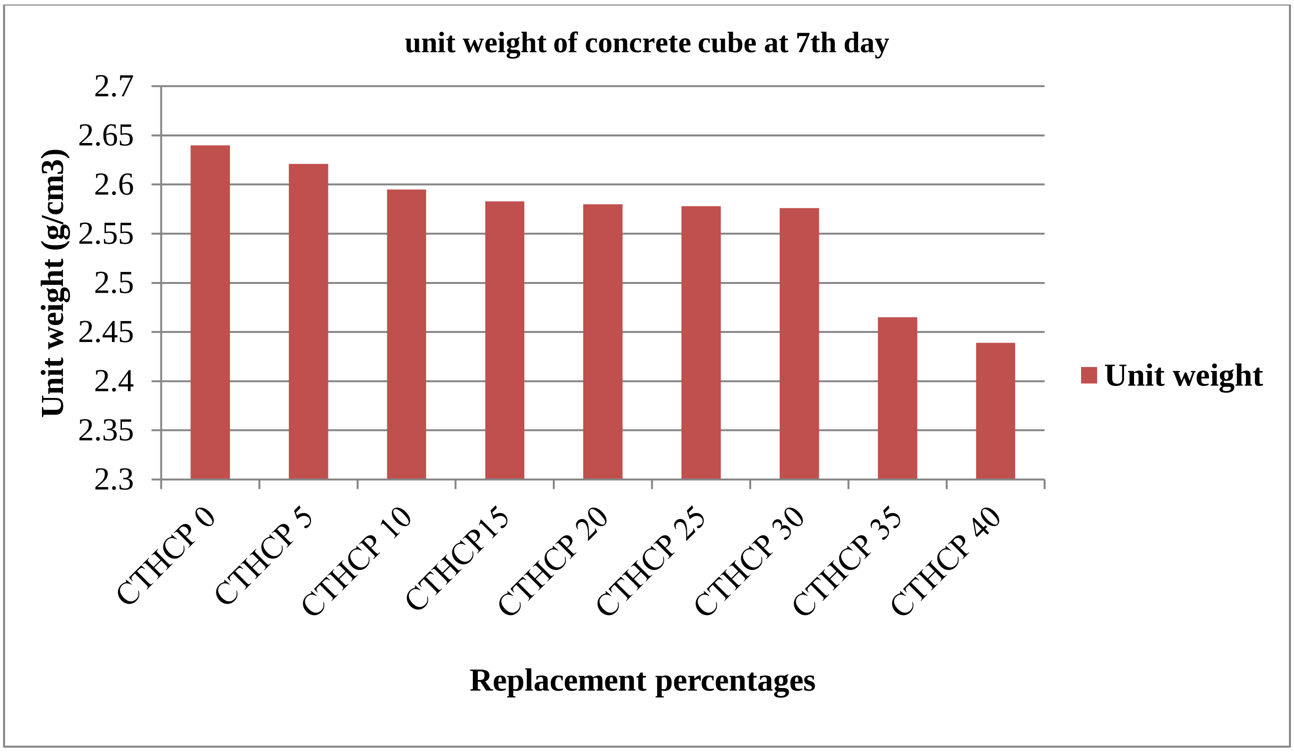



**Fig.4.10.Unit weight of concrete cubes at Seventh-day ages**

From the above table, it was found that a significant reduction of unit weight up to 6.63% - 7.61 % was observed when 35% and 40% of the cement was replaced by calcined termite hill clay powder respectively. On the other side 2.42%, 1.70%, 2.27%, 0.72%,2.16% and 2.35 % reductions were observed for 25%,20%,15%, 10%, and 5% of calcined termite hill clay powder respectively even though, the larger magnitude of reduction was observed as percentage of replacement increases.

This implies that the rationale behind this weight reduction is the density of replacing material (i.e., CTHCP) as compared to that of ordinary Portland cement. Then graphically, the reduction is also shown by bar graph above.

**Table 4.13. Unit weights of concrete cubes with CTHCP replacing percentages at 28th day**

| *S.№* | *Identity No.* | *Replacement (%)* | *Unit weights ($g/cm^3$)* | *Unit weight reduction (%)* |
|---|---|---|---|---|
| 1 | CTHCP-0 | 0 | 2.697 | 0.00 |
| 2 | CTHCP-5 | 5 | 2.65 | 0.047 |
| 3 | CTHCP-10 | 10 | 2.568 | 0.082 |
| 4 | CTHCP-15 | 15 | 2.559 | 0.009 |
| 5 | CTHCP-20 | 20 | 2.556 | 0.003 |
| 6 | CTHCP-25 | 25 | 2.546 | 0.01 |
| 7 | CTHCP-30 | 30 | 2.491 | 0.055 |
| 8 | CTHCP-35 | 35 | 2.475 | 0.016 |
| 9 | CTHCP-40 | 40 | 2.432 | 0.043 |

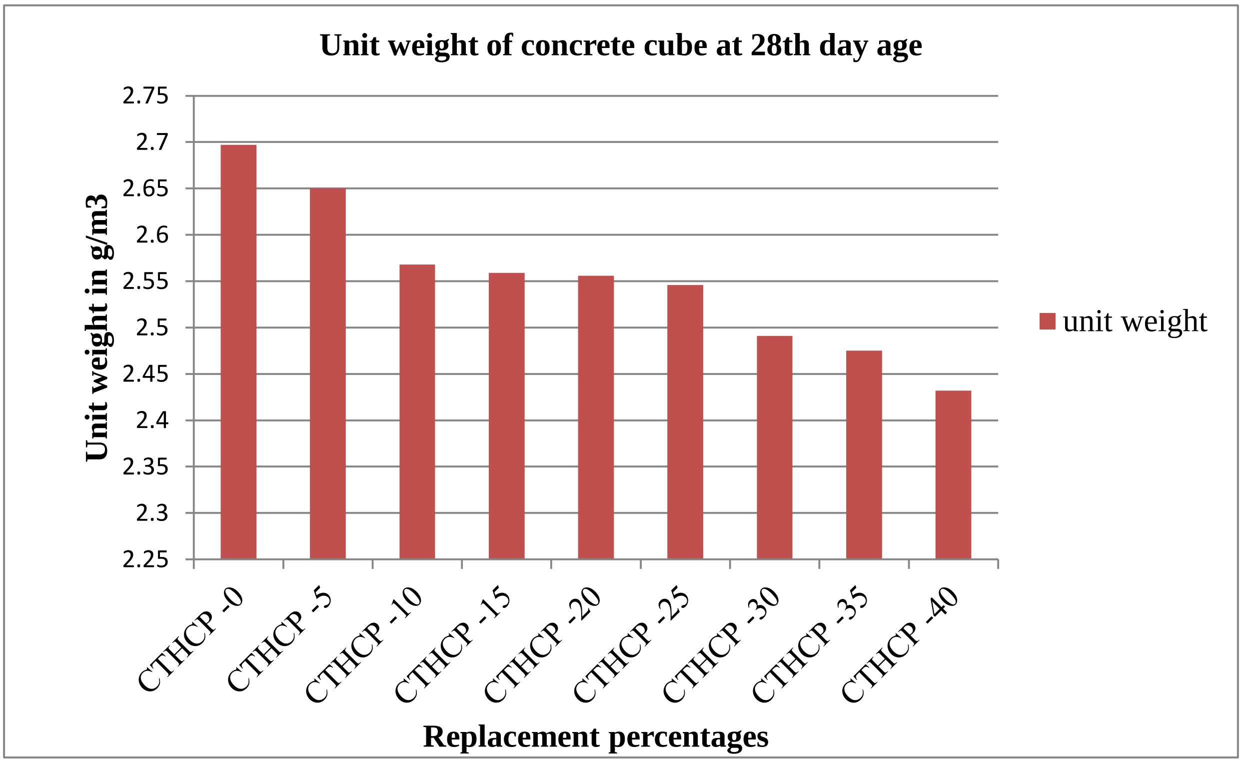



**Fig.4.11.Unit weight of concrete cubes at twenty-eight-day ages**

Despite the figure magnitude on the table above, the concretes with the calcined termite hill clay powder have shown a reduction in unit weight. A low-density concrete is beneficial in many ways over a high-density concrete. Using a lighter concrete reduces the size of structural members and also reduces the pressure on formworks.

#### 4.3.7.2. Compressive strength of concrete

One of the governing qualities of concrete is its compressive strength since the concrete is weak in tensile strength. This is the reason behind reinforcing the concrete in flexural members. The compressive strength test of concrete is the most common test type for the hardened concrete.

The reasons for these are; many codes and design manuals are based on this property, many other properties of concrete depend on the compressive strength, and when compared to other tests this is an easy one. The compressive strength of each of the concrete is determined by testing the cubes in a compression machine. For each of the mixes, the average value of three representative samples was taken as their compressive strength. Table 4.14. Shows this compressive strength values:

**Table 4.14. Average compressive strength of concrete**

| S.No | Identity No. | Average compressive strength | | | |
|---|---|---|---|---|---|
| | | 7th days | | 28th days | |
| | | Corrected max. Load (KN) | Strength(N/mm$^2$) | Corrected max. Load (KN) | Strength(N/mm$^2$) |
| 1 | CTHCP-0 | 659 | 29.3 | 792 | 35.19 |
| 2 | CTHCP-5 | 645 | 28.67 | 793 | 35.27 |
| 3 | CTHCP-10 | 579 | 25.74 | 815 | 36.22 |
| 4 | CTHCP-15 | 577 | 25.66 | 710 | 31.56 |
| 5 | CTHCP-20 | 526 | 23.38 | 694 | 30.84 |
| 6 | CTHCP-25 | 441 | 19.62 | 594 | 26.39 |
| 7 | CTHCP-30 | 407 | 18.1 | 509 | 22.65 |
| 8 | CTHCP-35 | 374 | 16.64 | 451 | 20.04 |
| 9 | CTHCP-40 | 304 | 13.53 | 428 | 19.02 |

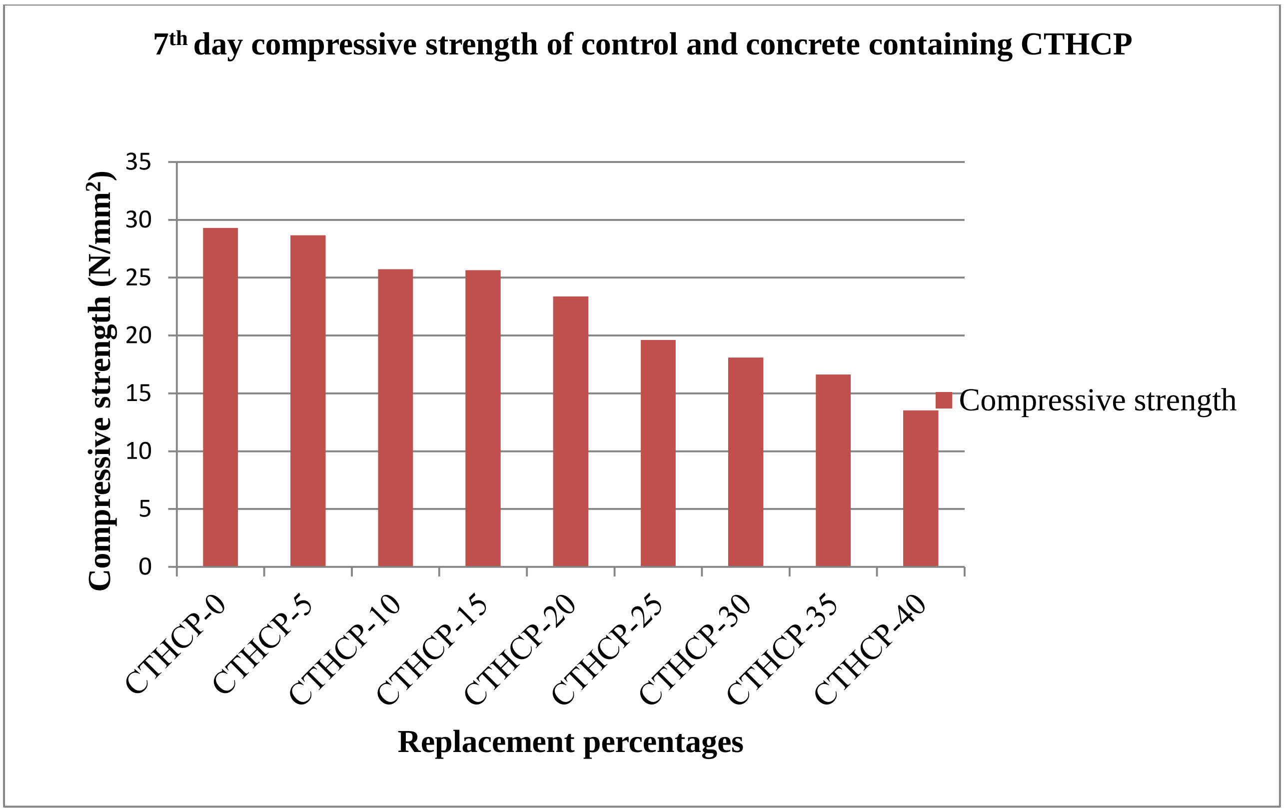



**Fig.4.12.7th-day compressive strength of cement blended with CTHCP concrete**

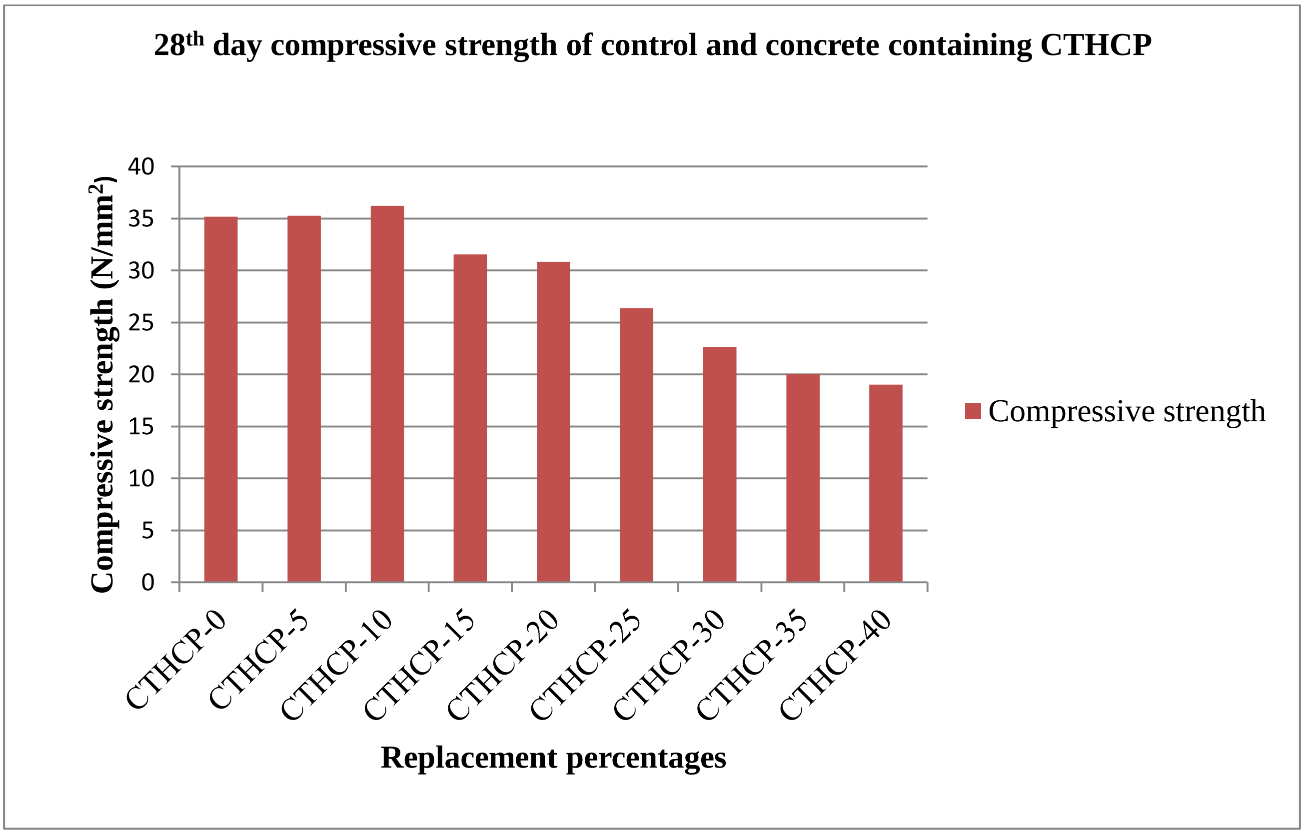



**Fig.4.13. 28th-day compressive strength of cement blended with CTHCP concrete**

According to [ACI-318 M, 02, Table-5.3.2.2], the 7th day's compressive strength of concrete is 67% of the targeted mean strength of the cubes after 28th days. This implies that compressive strength of cubes at 7th should be greater than 22MPa (i.e., 0.67*34MPa=22.78MPa).

The targeted 7th-day compressive strength of control mix was 22.78MPa. From Table 4.14, up to 20%, partial replacement of cement by calcined termite hill clay powder the compressive strength of the concrete has shown strength increase over the targeted strength.

On the contrary, from 25%-40% of replacement the strength of the concrete fall below the targeted strength. This indicates that the compressive strength of the concrete in which cement is partially replaced by the calcined termite hill clay powder decreases with increase in the calcined termite hill clay powder content. Probably, the case is the high replacement of cement by CTHCP thus reducing cement content of the mixture which in turn causes a reduction in the hydration reaction necessary for strength developments. Besides, dry states of calcined termite hill clay powder resulted in a higher water requirement, making the water unavailable for the hydration of the cement. Figure 4.12. Above shows the trend in compressive strength of the concrete formed from cement partially replaced by calcined termite hill clay powder at 7th day curing age.

Similarly, the 28th day's targeted mean strength of concrete should be 34MPa for the concrete to have compressive strength 25MPa. As indicated in the table 4.14. The 28th compressive strength of control cubes was found to be 35.19 $N/mm^2$. From the table above up 10% replacement, the compressive strength of the concrete cubes shows significant increments. This means; when cement partially replaced with CTHCP up to 5% the targeted mean strength increase with 0.23%. At 10% replacement, the strength shows more percentages of increments which is 2.93%. But, beyond this replacement range the strength of the concrete decrease significantly. Then finally, the pattern of strength changes as indicated by the bar graph on fig.4.13 above.

### 4.4. The optimal percentage of mix with Calcined Termite Hill Clay powder as the partial replacement of cement in production of grade C-25 concrete.

From the table 4.14. The 7th day compressive strength of concrete cubes shows the value greater than targeted mean strength of C-25 grade concrete up to 20% of partial replacement of cement with calcined termite hill clay powder. The compressive strength at 5%, 10%, 15% and 20% were found to be 28.87N/mm$^2$, 25.74 N/mm$^2$, 25.66 N/mm$^2$ and 23.38 N/mm$^2$ respectively. While the targeted mean strength to C-25 graded concrete is 22 N/mm$^2$. On the other hand, the 28th compressive strength of the concrete cubes produced with cement partial replaced by calcined termite hill clay powder has achieved the value greater than targeted mean strength for C-25 grade concrete only up to 10% partial replacement. This value is 35.27 N/mm$^2$ and 36.22 N/mm$^2$ for 5% and 10% partial replacement of calcined termite hill clay powder with cement respectively. The targeted mean compressive strength of C-25 graded concrete at 28th day is 34 N/mm$^2$. The optimal percentage of mix of partial replacement is the percentage at which cube strength is greater than targeted mean strength at 28th day. In determination the following line graph was used to determine the percentage of replacement at which compressive is greater than or equal to targeted mean strength of C-25 grade concrete.

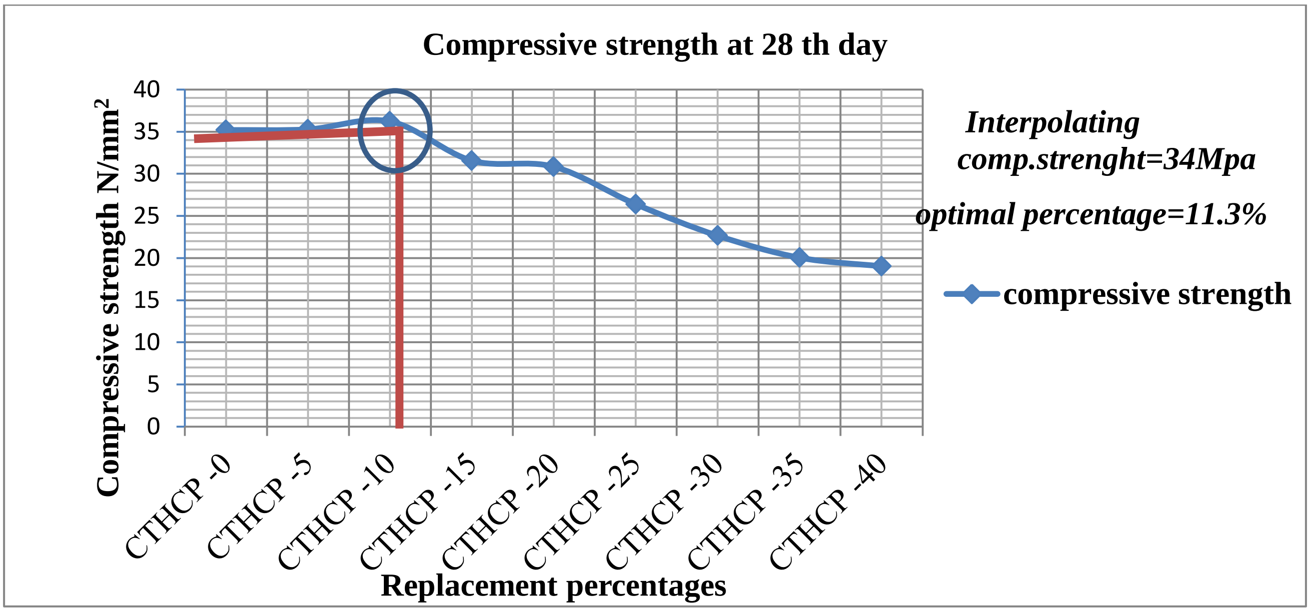



**Fig.4.14. Optimal percentages of mix determination for C-25 grade concrete**

From the graph above at 11.3% of partial replacement of cement by CTHCP, the compressive strength of the blended cube is equal to 34Mpa.

# CHAPTER FIVE

# CONCLUSION AND RECOMMENDATION

In this chapter, Conclusions and Recommendations that could be drawn from the results of this thesis work and experiments were summarized as follows:

## 5.1. Conclusion

Results of the experimental studies on calcined termite hill clay powder have been presented, and the following conclusions are made:

The chemical properties of calcined termite hill clay powder include the fact that the material is pozzolanic with the sum of $SiO_2$ (38.82%), $Al_2O_3$(23.98%), and $Fe_2O_3$(11.68%) constituting 74.48% of the material, leading to the conclusion that termite hill clay powder calcined at the temperature of 650$^{o}$C satisfied the requirement of ASTM C618 of minimum of 70%. Moreover, classified as natural Pozzolana class N.

Calcined termite hill powder had displayed pozzolanic property and classified under class N Pozzolana. Meaning that, the material can produce the cementitious compound that has binding property upon reaction with calcium hydroxide gained from hydration of cement. Therefore, calcined termite hill clay powder found suitable to partial replace cement in the production of concrete.

The quality of control materials; cement, mixing water, fine aggregates and coarse aggregate had shown compliance with the set standard criteria, thus leading to the conclusion that any significant effect on the tests having calcined termite hill clay powder as partial cement replacement was from CTHCP itself.

The workability of concrete containing calcined termite hill clay powder decreases, slightly as the calcined termite hill clay powder content increases, specially, at 30% (23mm),35% (22.3mm) and 40% (21mm) of partial replacement the slump found to be out of the targeted slump 25mm-75mm for C-25 grade concrete. Therefore, the concrete is not workable at replacement percentage greater than 25% of calcined termite hill clay powder with cement.

With the addition of calcined termite hill clay powder, compressive strength of concrete increased up to 20% partial replacement for 7th day age. Similarly, it shows increment only up 10% partial replacement at 28th day. This concluded that, higher percentage of calcined termite hill clay powder with cement decreases the compressive strength of C-25 concrete.

Up to 11.3% partial replacement of cement with calcined termite hill clay powder, it can be possible to produces C-25 grade concrete during its normal curing ages since the compressive strength of these replacement percentages exceeds the targeted mean strength of the control mix.

Higher replacements of cement by calcined termite hill clay powder resulted in higher normal consistency (implying higher water demand for certain workability) and shorter setting time.

The setting times of the paste is decreased. The initial and final setting time of the control mix is 151minute and 267minutes respectively. As replacement percentage increases, both initial and final setting time of the blended pastes had shown significant reduction and finally, at the far ends which is 40% replacement it was found to be 123minute for initial and 210minute for that of final setting time. This implies that calcined termite hill clay powder is a set accelerator and is good for cold weather concreting where early removal of formwork is needed.

The concrete produced with calcined termite hill clay powder was low density concrete due to the density of material as compared to that of cement.

## 5.2. Recommendations

1) It is recommended that calcined termite hill clay powder (CTHCP) can be used as the partial replacement for cement in the production of C-25 grade concrete as locally, available affordable construction material
2) Calcined termite hill clay powder as investigated in this research work can be used as a cement replacing material with much more environmental benefits. Therefore concerned bodies like government authority and cement industry stake holder should be made aware of this potential cement replacing material and promote its Standardized production (i.e., calcination and bringing desired fineness since calcined termite hill was coarser material than cement) and usage.

### 5.2.1. Recommendation on the areas of further studies

This research studied some of the basic physical and chemical properties of Bokuluboma calcined termite hill clay powder as a cement replacing material. However, further studies are required to the following areas:

- ✓ The effect of calcined termite hill clay powder used as partial cement replacement on the flexural strength and split tensile of the C-25 grade concrete.
- ✓ Durability of concrete produced from calcined termite hill clay powder used as partial cement replacing.
- ✓ The compressive strength of concrete produced from cement partial replaced with CTHCP at the ages beyond 28$^{th}$ day can be recommended as areas of further studies.

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# APPENDIX-1

## A.FINE AGGREGATE QUALITY TEST RESULTS

### 1. Unit weight of river sand

| *LOOSE DENSITY OF MOYALE RIVER SAND (AASHTO T-19)* | | | | | |
|---|---|---|---|---|---|
| **Sample station:** | 241+300 LHS (offset dist. 2.0 Km), Stock Pile | **Date Test** | 7/28/2017 | | |
| **Visual description of material:** | Moyale River Sand | **Source:** | CH. 291+300 RHS (Offset 3.5km) | | |
| **Purpose:** | For Concrete Work | **RFI No.** | for research purpose | | |
| **Date Sample:** | 7/24/2017 | **Lab. No.** | 1 | | |
| *A) LOOSE DENSITY* | | | | | |
| S. No | Description | Trial-1 | Trial-2 | Trial-3 | Average (g/cc) |
| 1 | Container weight (g) | 2688 | 2688 | 2688 | |
| 2 | Volume of container (cc) | 3468.33 | 3468.33 | 3468.33 | |
| 3 | Weight of material + container (g) | 7632 | 7630 | 7625 | |
| 4 | Bulk density of material (g/cc) | 1.425 | 1.425 | 1.423 | |

**2. Specific gravity of river sand**

| SPECIFIC GRAVITY & WATER ABSORPTION (AASHTO T-85) | | | | |
|---|---|---|---|---|
| **Sample Station:** | CH. 241+300 LHS (Offset 2.0km) | **Date Test :** | 7/27/2017 | |
| **Visual description of material:** | River Sand | **Source:** | CH. 291+300 RHS (Offset 3.5 km) | |
| **Purpose:** | For Concrete Mix Design | **RFI NO.** | for research purpose | |
| **Date Sample:** | 7/26/2017 | **Lab Job No.** | | |
| **Description of sample** | | **Test 1** | **Test 2** | **Average** |
| **Weight of Pyconometer (g)** | | 347.6 | 364.1 | |
| **A = Weight of Pyconometer + SSD sample + water (g)** | | 1772 | 1783.1 | |
| **B = Weight of Pyconometer + water (g)** | | 1459.1 | 1469.5 | |
| **C = Weight of SSD sample (g)** | | 500 | 500.0 | |
| **D = Weight of oven dry sample (g)** | | 494.39 | 495.2 | |
| **SSD Bulk Specific Gravity, C/{C-(A-B)}** | | 2.672 | 2.682 | 2.677 |
| **Bulk Specific Gravity, D/{C-(A-B)}** | | 2.642 | 2.657 | 2.650 |
| **Apparent Specific Gravity, D/{D-(A-B}** | | 2.724 | 2.727 | 2.725 |
| **Water absorption, percentage, 100 X (C-D)/D** | | 1.135 | 0.969 | 1.052 |

### 3. Silt contents of the sand

| SILT CONTENT DETERMINATION (AASHTO T-11) | | | | | |
|---|---|---|---|---|---|
| **Sample station:** | CH. 241+300 LHS (Offset 2.0km) | | **Date Test** | 2/27/2017 | |
| **Visual description of material:** | river sand | | **Source:** | 291+200 RHS (Offset 3.5 km) & JMC Crusher Plant | |
| **Purpose:** | For Concrete | | **Lab. No.** | | |
| **Date Sample:** | 2/24/2017 | | **RFI No.** | for research purpose | |
| **Trial No.** | **1 & 2** | | **Depth** | From Stock | |
| **Trial No** | **Wt. before washing (g)** | **Wt. after washing (g)** | **Clay Content (g)** | **silt Content (%age)** | **Avg. silt Content (%)** |
| 1 | 1109.0 | 1105.1 | 3.90 | 0.35 | 0.35 |
| 2 | 1057.0 | 1053.3 | 3.70 | 0.35 | |

## B.COARSE AGGREGATE QUALITY TEST RESULTS

1. **Loose and dry rodded unit weight**

| LOOSE & RODDED DENSITY | | | | |
|---|---|---|---|---|
| **Sample Station:** | CH. 241+300 LHS (Offset 2.0km) | **Date Test :** | 7/25/2017 | |
| **Visual description of material:** | 19mm Aggregate | **Source:** | precast yard (offset 0.5km) | |
| **Purpose:** | For Concrete | **Lab No.** | for research purpose | |
| **Date Sample:** | 7/24/2017 | **RFI No.** | | |
| | | **Depth** | From Stock Pile | |
| **Loose Density** | | | | |
| **Description** | **Trial 1** | **Trial 2** | **Trial 3** | **Average** |
| **Wt of Agg. + Calibration container (g)** | 7808 | 7792 | 7800 | |
| **Wt. of Cylinder (g)** | 2683 | 2683 | 2683 | |
| **Wt. of Agg. (g)** | 5125 | 5109 | 5117 | |
| **Volume of cylinder (cc)** | 3468.33 | 3468.33 | 3468.33 | |
| **unit weight (g/cc)** | 1.478 | 1.473 | 1.475 | 1.475 |
| **Dry Rodded Density** | | | | |
| **Description** | **Trial 1** | **Trial 2** | **Trial 3** | **Average** |
| **Wt of Agg. + Calibration container (g)** | 8170 | 8215 | 8208 | |
| **Wt. of Cylinder (g)** | 2683 | 2683 | 2683 | |
| **Wt. of Agg. (g)** | 5487 | 5532 | 5525 | |
| **Volume of cylinder (cc)** | 3468.33 | 3468.33 | 3468.33 | |
| **unit weight (g/cc)** | 1.582 | 1.595 | 1.593 | 1.590 |

**2. Specific gravity of coarse aggregate**

| SPECIFIC GRAVITY & WATER ABSORPTION (AASHTO T-85) | | | | |
|---|---|---|---|---|
| **Sample station:** | 241+300 LHS (offset dist. 2.0 Km) | **Date Test** | 7/26/017 | |
| **Visual description of material:** | Crushed Aggregate(19 MM) | **Source:** | JMC Crusher | |
| **Purpose:** | For Concrete Work | **Lab. No.** | for research purpose | |
| **Date Sample:** | 7/25/2017 | **RFI No.** | | |
| **Description of sample** | | **19 mm** | **19 mm** | **Average** |
| **A = Weight of Oven dry sample in air (g)** | | 2971.5 | 2928.3 | |
| **B = Weight of SSD sample in air (g)** | | 2987.3 | 2941.6 | |
| **C = Weight of sample in water (g)** | | 1860.7 | 1832.9 | |
| **D= Water Temperature (*C)** | | 25.0 | 25.0 | |
| **E= Specific Gravity of Water** | | 1.000 | 1.000 | |
| **F = Bulk Specific Gravity (Oven Dry) sd= A*E/(B-C)** | | 2.638 | 2.641 | |
| **G = Bulk Specific Gravity (SSD) ss= B*E/(B-C)** | | 2.652 | 2.653 | 2.652 |
| **H = Apparent Specific Gravity, Sr= A*E/(A-C)** | | 2.675 | 2.673 | 2.674 |
| **I = Water absorption, percentage, 100 X (B-A)/A** | | 0.53 | 0.45 | 0.49 |

## APPENDIX-2

### A.COMPRESSIVE STRENGTH AND SLUMP OF CONCRETE CUBES WITH CTHCP

**1. Control mix**

| COMPRESSIVE STRENGTH TEST OF CONCRETE CUBE (Test Method BS1881-116) | | | | | | |
|---|---|---|---|---|---|---|
| **Structure:** | for all conc. Structure | | **Source of sand:** | CH.291+300 RHS (offset 3.5km) | | |
| **Concrete class:** | C-25 | | **Source of aggregate:** | JMC Crusher Plant | | |
| **Cast date:** | 7/29/2017 | | **Source of water:** | Crusher Plant | | |
| **Volume of mold (cu cm):** | 3375 | | **water binder ratio:** | 0.5 | | |
| **Area of crushing face (sq.cm):** | 225 | | **Cement content (kg/cu m):** | 360 kg | | |
| **RFI No** | For Research | | **CTHCP contents (kg/cu m): 0%** | 0 kg | | |
| **Date of testing** | **8/5/2017** | | | **8/26/2017** | | |
| **Age in days** | **7 days** | | | **28 days** | | |
| **Specimen no** | **1** | **2** | **3** | **4** | **5** | **6** |
| **Slump (mm)** | 35 | 35 | 35 | 35 | 35 | 35 |
| **Weight (g)** | 9047 | 8988 | 8694 | 8703 | 8732 | 8856 |
| **Density (kg/cum)** | 2.681 | 2.663 | 2.576 | 2.579 | 2.587 | 2.624 |
| **Max. load at failure (KN)** | 649 | 580 | 497 | 548 | 878 | 652 |
| **Corrected Max.load at failure (KN)** | 742.4 | 664.5 | 570.9 | 628 | 1001 | 746 |
| **Compressive Strength (Mpa)** | 33.0 | 29.5 | 25.4 | 28 | 44 | 33 |
| **Avg. compressive Strength (Mpa)** | 29.30 | | | 35.19 | | |

**2. 5% partial replacement**

| COMPRESSIVE STRENGTH TEST OF CONCRETE CUBE (Test Method BS1881-116) | | | | | | |
|---|---|---|---|---|---|---|
| **Structure:** | for all conc. Structure | **Source of sand:** | | CH.291+300 RHS (offset 3.5km) | | |
| **Concrete class:** | C-25 | **Source of aggregate:** | | JMC Crusher Plant | | |
| **Cast date:** | 7/29/2017 | **Source of water:** | | Crusher Plant | | |
| **Volume of mold (cu cm):** | 3375 | **water binder ratio:** | | 0.5 | | |
| **Area of crushing face (sq.cm):** | 225 | **Cement content (kg/cu m):** | | 342 kg | | |
| **RFI No** | For Research | **CTHCP contents (kg/cu m): 5%** | | 18 kg | | |
| **Date of testing** | 8/5/2017 | | | 8/26/2017 | | |
| **Age in days** | **7 days** | | | **28 days** | | |
| **Specimen no** | **1** | **2** | **3** | **4** | **5** | **6** |
| **Slump (mm)** | 35 | 35 | 35 | 35 | 35 | 35 |
| **Weight (g)** | 8686 | 8595 | 8817 | 9043 | 9010 | 8779 |
| **Density (kg/cum)** | 2.574 | 2.547 | 2.612 | 2.679 | 2.670 | 2.601 |
| **Max. load at failure (KN)** | 647 | 538 | 503 | 717 | 679 | 687 |
| **Corrected Max.load at failure (KN)** | 740.2 | 617.1 | 577.6 | 819 | 776 | 785 |
| **Compressive Strength (Mpa)** | 32.9 | 27.4 | 25.7 | 36 | 35 | 35 |
| **Avg. compressive Strength (Mpa)** | 28.67 | | | 35.27 | | |

### 3. 10% replacement

| COMPRESSIVE STRENGTH TEST OF CONCRETE CUBE (Test Method BS1881-116) | | | | | | |
|---|---|---|---|---|---|---|
| **Structure:** | for all conc. Structure | | **Source of sand:** | CH.291+300 RHS (offset 3.5km) | | |
| **Concrete class:** | C-25 | | **Source of aggregate:** | JMC Crusher Plant | | |
| **Cast date:** | 7/31/2017 | | **Source of water:** | Crusher Plant | | |
| **Volume of mold (cu cm):** | 3375 | | **water binder ratio:** | 0.5 | | |
| **Area of crushing face (sq.cm):** | 225 | | **Cement content (kg/cu m):** | 324 kg | | |
| **RFI No** | For Research | | **CTHCP contents (kg/cu m): 10%** | 36 kg | | |
| **Date of testing** | 7/8/2017 | | | 8/28/2017 | | |
| **Age in days** | **7 days** | | | **28 days** | | |
| **Specimen no** | **1** | **2** | **3** | **4** | **5** | **6** |
| **Slump (mm)** | 29 | 29 | 29 | 29 | 29 | 29 |
| **Weight (g)** | 8573 | 8898 | 8680 | 8811 | 8299 | 8891 |
| **Density (kg/cum)** | 2.540 | 2.636 | 2.572 | 2.611 | 2.459 | 2.634 |
| **Max. load at failure (KN)** | 495 | 49111 | 527 | 620 | 805 | 715 |
| **Corrected Max.load at failure (KN)** | 568.6 | 564.1 | 604.7 | 710 | 918 | 817 |
| **Compressive Strength (Mpa)** | 25.3 | 25.1 | 26.9 | 32 | 41 | 36 |
| **Avg. compressive Strength (Mpa)** | 25.74 | | | 36.22 | | |

4. **15% replacements**

| COMPRESSIVE STRENGTH TEST OF CONCRETE CUBE (Test Method BS1881-116) | | | | | | |
|---|---|---|---|---|---|---|
| **Structure:** | for all conc. Structure | | **Source of sand:** | CH.291+300 RHS (offset 3.5km) | | |
| **Concrete class:** | C-25 | | **Source of aggregate:** | JMC Crusher Plant | | |
| **Cast date:** | 7/31/2017 | | **Source of water:** | Crusher Plant | | |
| **Volume of mold (cu cm):** | 3375 | | **water binder ratio:** | 0.5 | | |
| **Area of crushing face (sq.cm):** | 225 | | **Cement content (kg/cu m):** | 306 kg | | |
| **RFI No** | For Research | | **CTHCP contents (kg/cu m): 15%** | 54 kg | | |
| **Date of testing** | 7/8/2017 | | | 8/28/2017 | | |
| **Age in days** | **7 days** | | | **28 days** | | |
| **Specimen no** | **1** | **2** | **3** | **4** | **5** | **6** |
| **Slump (mm)** | 28 | 28 | 28 | 28 | 28 | 28 |
| **Weight (g)** | 8716 | 8961 | 8861 | 8708 | 8710 | 8899 |
| **Density (kg/cum)** | 2.583 | 2.655 | 2.625 | 2.580 | 2.581 | 2.637 |
| **Max. load at failure (KN)** | 507 | 521 | 480 | 652 | 620 | 589 |
| **Corrected Max.load at failure (KN)** | 582.2 | 598.0 | 551.7 | 746 | 710 | 675 |
| **Compressive Strength (Mpa)** | 25.9 | 26.6 | 24.5 | 33 | 32 | 30 |
| **Avg. compressive Strength (Mpa)** | 25.66 | | | 31.56 | | |

5. **20% replacements**

| COMPRESSIVE STRENGTH TEST OF CONCRETE CUBE (Test Method BS1881-116) | | | | | | |
|---|---|---|---|---|---|---|
| **Structure:** | for all conc. Structure | | **Source of sand:** | CH.291+300 RHS (offset 3.5km) | | |
| **Concrete class:** | C-25 | | **Source of aggregate:** | Jmc Crusher Plant | | |
| **Cast date:** | 8/1/2017 | | **Source of water:** | Crusher Plant | | |
| **Volume of mold (cu cm):** | 3375 | | **water binder ratio:** | 0.5 | | |
| **Area of crushing face (sq.cm):** | 225 | | **Cement content (kg/cu m):** | 288 kg | | |
| **RFI No** | For Research | | **CTHCP contents (kg/cu m): 20%** | 72 kg | | |
| **Date of testing** | 8/8/2017 | | | 8/29/2017 | | |
| **Age in days** | **7 days** | | | **28 days** | | |
| **Specimen no** | **1** | **2** | **3** | **4** | **5** | **6** |
| **Slump (mm)** | 26 | 26 | 26 | 26 | 26 | 26 |
| **Weight (g)** | 8603 | 8652 | 8868 | 8767 | 8663 | 8951 |
| **Density (kg/cum)** | 2.549 | 2.564 | 2.628 | 2.598 | 2.567 | 2.652 |
| **Max. load at failure (KN)** | 442 | 444 | 486 | 577 | 680 | 561 |
| **Corrected Max.load at failure (KN)** | 508.8 | 511.1 | 558.5 | 661 | 777 | 643 |
| **Compressive Strength (Mpa)** | 22.6 | 22.7 | 24.8 | 29 | 35 | 29 |
| **Avg. compressive Strength (Mpa)** | 23.38 | | | 30.84 | | |

6. **25% replacements**

| COMPRESSIVE STRENGTH TEST OF CONCRETE CUBE (Test Method BS1881-116) | | | |
|---|---|---|---|
| **Structure:** | for all conc. Structure | **Source of sand:** | CH.291+300 RHS (offset 3.5km) |
| **Concrete class:** | C-25 | **Source of aggregate:** | JMC Crusher Plant |
| **Cast date:** | 8/1/2017 | **Source of water:** | Crusher Plant |
| **Volume of mold (cu cm):** | 3375 | **water binder ratio:** | 0.5 |
| **Area of crushing face (sq.cm):** | 225 | **Cement content (kg/cu m):** | 270 kg |
| **RFI No** | For Research | **CTHCP contents (kg/cu m): 25%** | 90 kg |

| **Date of testing** | 8/8/2017 | | | 8/29/2017 | | |
|---|---|---|---|---|---|---|
| **Age in days** | **7 days** | | | **28 days** | | |
| **Specimen no** | **1** | **2** | **3** | **4** | **5** | **6** |
| **Slump (mm)** | 25 | 25 | 25 | 25 | 25 | 25 |
| **Weight (g)** | 8802 | 8722 | 8753 | 8581 | 8672 | 8529 |
| **Density (kg/cum)** | 2.608 | 2.584 | 2.593 | 2.543 | 2.569 | 2.527 |
| **Max. load at failure (KN)** | 341 | 381 | 425 | 557 | 502 | 493 |
| **Corrected Max.load at failure (KN)** | 394.8 | 439.9 | 489.6 | 639 | 577 | 566 |
| **Compressive Strength (Mpa)** | 17.5 | 19.6 | 21.8 | 28 | 26 | 25 |
| **Avg. compressive Strength (Mpa)** | 19.62 | | | 26.39 | | |

### 7. 30% replacements

| COMPRESSIVE STRENGTH TEST OF CONCRETE CUBE (Test Method BS1881-116) | | | | | | |
|---|---|---|---|---|---|---|
| **Structure:** | for all conc. Structure | | **Source of sand:** | CH.291+300 RHS (offset 3.5km) | | |
| **Concrete class:** | C-25 | | **Source of aggregate:** | JMC Crusher Plant | | |
| **Cast date:** | 8/1/2017 | | **Source of water:** | Crusher Plant | | |
| **Volume of mold (cu cm):** | 3375 | | **water binder ratio:** | 0.5 | | |
| **Area of crushing face (sq.cm):** | 225 | | **Cement content (kg/cu m):** | 252 kg | | |
| **RFI No** | For Research | | **CTHCP contents (kg/cu m): 30%** | 108 kg | | |
| **Date of testing** | 8/8/2017 | | | 8/29/2017 | | |
| **Age in days** | **7 days** | | | **28 days** | | |
| **Specimen no** | 1 | 2 | 3 | 4 | 5 | 6 |
| **Slump (mm)** | 23 | 23 | 23 | 23 | 23 | 23 |
| **Weight (g)** | 8609 | 8873 | 8598 | 8298 | 8167 | 8751 |
| **Density (kg/cum)** | 2.551 | 2.629 | 2.548 | 2.459 | 2.420 | 2.593 |
| **Max. load at failure (KN)** | 344 | 340 | 372 | 397 | 516 | 415 |
| **Corrected Max. load at failure (KN)** | 398.2 | 393.7 | 429.8 | 458 | 592 | 478 |
| **Compressive Strength (Mpa)** | 17.7 | 17.5 | 19.1 | 20 | 26 | 21 |
| **Avg. compressive Strength (Mpa)** | 18.10 | | | 22.65 | | |

**8. 35% replacements**

| COMPRESSIVE STRENGTH TEST OF CONCRETE CUBE (Test Method BS1881-116) | | | | | | |
|---|---|---|---|---|---|---|
| **Structure:** | for all conc. Structure | | **Source of sand:** | | CH.291+300 RHS (offset 3.5km) | |
| **Concrete class:** | C-25 | | **Source of aggregate:** | | Jmc Crusher Plant | |
| **Cast date:** | 8/2/2017 | | **Source of water:** | | Crusher Plant | |
| **Volume of mold (cu cm):** | 3375 | | **water binder ratio:** | | 0.5 | |
| **Area of crushing face (sq.cm):** | 225 | | **Cement content (kg/cu m):** | | 234 kg | |
| **RFI No** | For Research | | **CTHCP contents (kg/cu m): 35%** | | 126 kg | |
| **Date of testing** | 8/9/2017 | | | 8/30/2017 | | |
| **Age in days** | **7 days** | | | **28 days** | | |
| **Specimen no** | **1** | **2** | **3** | **4** | **5** | **6** |
| **Slump (mm)** | 22.3 | 22.3 | 22.3 | 22.3 | 22.3 | 22.3 |
| **Weight (g)** | 8378 | 8425 | 8160 | 8558 | 8431 | 8471 |
| **Density (kg/cum)** | 2.482 | 2.496 | 2.418 | 2.536 | 2.498 | 2.510 |
| **Max. load at failure (KN)** | 307 | 321 | 341 | 359 | 400 | 413 |
| **Corrected Max.load at failure (KN)** | 356.4 | 372.2 | 394.8 | 415 | 461 | 476 |
| **Compressive Strength (Mpa)** | 15.8 | 16.5 | 17.5 | 18 | 21 | 21 |
| **Avg. compressive Strength (Mpa)** | 16.64 | | | 20.04 | | |

**9. 40% replacements**

| COMPRESSIVE STRENGTH TEST OF CONCRETE CUBE (Test Method BS1881-116) | | | | | |
|---|---|---|---|---|---|
| **Structure:** | for all conc. Structure | | **Source of sand:** | CH.291+300 RHS (offset 3.5km) | |
| **Concrete class:** | C-25 | | **Source of aggregate:** | JMC Crusher Plant | |
| **Cast date:** | 8/2/2017 | | **Source of water:** | Crusher Plant | |
| **Volume of mold (cu cm):** | 3375 | | **water binder ratio:** | 0.5 | |
| **Area of crushing face (sq.cm):** | 225 | | **Cement content (kg/cu m):** | 216 kg | |
| **RFI No** | For Research | | **CTHCP contents (kg/cu m): 40%** | 144 kg | |
| | | | | | |
| **Date of testing** | 8/9/2017 | | | 8/30/2017 | |
| **Age in days** | **7 days** | | | **28 days** | |
| **Specimen no** | 1 | 2 | 3 | 4 | 5 | 6 |
| **Slump (mm)** | 21 | 21 | 21 | 21 | 21 | 21 |
| **Weight (g)** | 8428 | 8051 | 8217 | 8587 | 8383 | 8669 |
| **Density (kg/cum)** | 2.497 | 2.385 | 2.435 | 2.544 | 2.484 | 2.569 |
| **Max. load at failure (KN)** | 264 | 275 | 244 | 405 | 332 | 374 |
| **Corrected Max.load at failure (KN)** | 307.9 | 320.3 | 285.3 | 467 | 385 | 432 |
| **Compressive Strength (Mpa)** | 13.7 | 14.2 | 12.7 | 21 | 17 | 19 |
| **Avg. compressive Strength (Mpa)** | 13.53 | | | 19.02 | | |

# APPENDIX-3

## A.CEMENT, WATER QUALITY TESTS AND CHEMICAL COMPOSITION OF CTHCP

### 1. Cement

**International Consultants and Technocrats Ethiopia Private Limited Company**

TEST RESULTS

LAB. No. : MMRP 1392/16 SAMPLED BY : The Client

CLIENT : JMC Projects (India) Ltd., TEST SPECIFIED BY : The Client

PROJECT : Construction work of Mombassa - Nairobi - Addis Ababa road Corridor, Lot III Mega Moyale Road project DATE SAMPLED : --

MATERIAL TYPE : Cement Dangote (OPC) DATE SUBMITTED : 29.09.2016

SOURCE : Store of JMC at Bokku site DATE ISSUED : 07.10.2016

| SI. No. | Test Type | Test result |
|---|---|---|
| 1 | Consistency (%) | 25 |
| 2 | Initial Setting time (minute) | 151 |
| 3 | Final Setting time (minute) | 267 |
| 4 | Soundness (mm) | 2 |
| 5 | Specific Surface Area, Fineness ($m^2$ /kg) ASTM C 204 | 334.4 |

Remark : - Test coducted as per AASHTO Standard.

Checked by:

Approved by:

International Consultants & Technocrats Ethiopia Private Limited Company Addis Ababa

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## 2. Water

የኢትዮጵያ ኮንስትራክሽን ዲዛይንና ሱፐርቪዥን ሥራዎች ኮርፖሬሽን
ምርምር፣ ላቦራቶሪና ስልጠና ማዕከል
የውሃ ጥራት ክፍል

Ethiopian Construction Design and Supervision Works Corporation
Research, Laboratory and Training Center
Water Quality Section
P.O.Box 2561
Addis Ababa

Tel. 251 - 118-693-618/285-410
Fax. 251 - 116 - 61 53 71/61 08 98
e-mail w.w.d.s.e@ethionet.et

SELECTED PHYSICO-CHEMICAL WATER ANALYSIS RESULTS

Client/Project: JMC Projects (Indian) Ltd. (Ethiopia Branch)

| SOURCE OF SAMPLE | Bore Well | Bore Well | | | WHO maximum allowable Concentration (mg/l) |
|---|---|---|---|---|---|
| LOCATION | CH2-241 + 300LHS | CH2-241 + 300LHS | | | |
| DATE OF COLLECTION | 28/2/2017 | 28/2/2017 | | | |
| DATE RECEIVED | 21/6/2017 | 21/6/2017 | | | |
| CLIENTS ID.NO. | Plant Site | Camp Site | | | |
| LAB.ID NO. | 5080/2009 | 5081/2009 | | | |
| pH | 7.40 | 7.41 | | | 6.5-8.5 |
| Electrical Conductivity (µS/cm) | 784.00 | 715.00 | | | – |
| T. Dissolved Solid $105^0C$(mg/l) | 522.00 | 474.00 | | | 1000.0 |
| Alkalinity (mg/l $CaCO_3$) | 237.50 | 212.80 | | | – |
| Carbonate (mg/l $CO_3^{2-}$) | Nil | Nil | | | – |
| Bicarbonate (mg/l $HCO_3^-$) | 289.75 | 259.62 | | | – |
| Chloride (mg/l $Cl^-$) | 86.53 | 77.18 | | | 250.0 |
| Sulphate (mg/l $SO^{2-}_4$) | 52.88 | 53.81 | | | 400.0 |

REMARK:-
- The test result can be compared with the WHO maximum allowable concentration (mg/l) indicated on the last column; but it is not Sufficent to decide the suitability of water for drinking purpose based on these parameters only .
- The water sample was collected and submitted to our laboratory by the client .

Tested by: ______ Date: 28/6/17
Processed By ______ Date 28-6-17
Checked by: ______ Date 28/06/17
Approved by: ______ Date: 28/6/2017

## 3. Chemical composition of CTHCP

Geological Survey of Ethiopia:Geochemical Laboratory Directorate

Geochemical Laboratory Complete Silicate Analysis Report Format — Form G0004

FILE ID 1613/17 Originator:Guya konso Danbata

Sample type;clay soil Date Submmitted;06/22/2017

Preparation :-200 MESH

Number of Sample: 1 Element to be determined Major Oxides & Minor Oxides

Analytical Method: LiBO2 FUSION , HFattack,GRAVIMETERIC,COLORIMETRIC and AAS

Analytical Results in PERCENT

| FIELD NO | Lab No | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $Na_2O$ | $K_2O$ | MnO | $P_2O_5$ | $TiO_2$ | $H_2O$ | LOI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CTHCP-01 | 1613/17 | 38.82 | 23.98 | 11.68 | 19.22 | 12.64 | 0.24 | 0.28 | <0.01 | 0.05 | 0.16 | 0.77 | 21.06 |

Analysts
Tizita Zemene
Dessie Abebe
Tihitna Beletkachew
Tamiru Siraye
Yohannes Getachew

Checked by: Tamiru Siraye

Approved by: Demisew Lemma

Quality Control: Awash Yirga

DATE REPORTED: 7/14/2017

Geological Survey of Ethiopia Central Geological Laboratory

Page 1 of 1

**APPENDIX-4**

**PHOTO GALLERY OF SOME LABORATORY EXPERIMENTS**

1. **photo taken during sand sampling from JMC stock pile**


2. **Photo taken during coarse aggregate sampling from JMC stock pile**

3. **Photograph taken at Dida china where termite hill abundant.**

4. **During sampling of termite hill material**

5. **Loading of sampled material to pick up**

**6. Riffle box**

**7. Sample quartering using riffle box prior to any experiments**

**8. Dry rodded and loose unit weight determination**

**9. During natural moisture content determination**

**10. SSD and silt contents of the sand**

**11. Oven and compression testing machine**

**12. During mixing and preparing cubes**

**13. Casting and curing**

**14.  Cube crushing**