Jimma University Institute Of Technology

Faculty Of Civil And Environmental Engineering

Department Of Civil Engineering

(Construction Engineering and Management)

A Comparative Study On Mitigation Of The Effect Of Silt And Clay Content Of Sand So As To Maintain The Fresh And Hardened Properties Of Concrete Arround Jimma

A Thesis Submitted To school of graduate study of Jimma University Institute Of technology Department Of Civil Engineering In Partial Fulfillment Of The Requirements For The degree Of Masters Science In Construction Engineering And Management

By:-Belete Worke

October 2017

JIMMA, ETHIOPIA

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By:-Belete Worke

Advisor:- Dr-Eng'r Tamene Adugna(PhD)

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DECLARATION

I, the undersigned, declare that this thesis entitled "A Comparative study on mitigation of the effect of silt and clay content of sand to maintain the fresh and hardened properties of concrete around Jimma " 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 theses have been duly acknowledged.

Candidate:

Belete Worke Dagne

Signature- ____________ Date-____________

As Master research Advisors, we hereby certify that we have read and evaluated this MSc. research prepared under our guidance, by Belete Worke entitled: "A Comparative study on mitigation of the effect of silt and clay content of sand to maintain the fresh and hardened properties of concrete around Jimma" We recommend that it can be submitted as fulfilling the MSc Thesis requirements.

Dr-Eng'r Tamene Adugna

Advisor ____________ ____________

Signature Date

Eng'r. Moges Getahun

Co-Advisor ____________ ____________

Signature *Date*

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ABSTRACT

Aggregate supply from local sources play a fundamental role in cost effective concrete production. But locally available Natural fine aggregate consist of some impurities like silt and clay which causes problems in fresh and hardened property of concrete, such as decreasing workability and compressive strength of concrete.

The general objective of the research was to mitigate the effect of silt and clay content of sand so as to maintain the fresh and hardened properties of concrete. In these research three methods was used to mitigate the effect of silt and clay. These are washing the sand to make free of silt and clay, adding extra cement on predetermined cement and blending with quality sand having silt and clay below Ethiopian standard. In washing the sand, the time and the amount of water needed to wash specific volume of sand was also determined. For this study the sand was collected from six supply point to Jimma such as, Asendabo, Nada, Yedi, Chewak, Werabe and Gambela and their level of silt and clay content was determined. Then Five samples of sand with varying silt and clay was taken (i. e 0.94%, 6%, 10%, 14%, and 18%) and three cubes (of 150 x 150 x 150 mm3) of 1:2:3 mixture with water cement ratio of 0.5 for compressive strength at 7 and 28 days of curing time was made for each percentage of silt and clay and the percentage strength reduction has been determined. Then another four sample with silt and clay content having the same value to the above five sample except 0.94% was prepared and for each percent of silt and clay, a three trial of cement increment was applied and three cubes for compressive strength at 7 and 28 days of curing time was made for each trial of cement increment.

As a result, it has been found that the sand being supplied to Jimma town contained silt and clay content that exceeded the allowable limit specified on Ethiopian standard. It ranges from 2.5% to 20%. As the silt and clay content of sand increase from 0.94% to 18%, the percentage reduction of the compressive strength is 46.12%. The addition of cement improves the workability and the compressive strength of concrete. As the silt and clay increase from 0.94% to 18%, 27% of additional cement was required to eliminates the negative effects of silt and clay in aggregates and to maintain the required workability and strength of concrete. And also the extra cost incurred in the production of 1m3 of concrete in terms of washing the sand was between 4.73-11.5% whereas cement increment was between 2.5-15.4% depending on the amount of silt and clay. And also it has been found that blending of 30% Asendabo sand with 70% Gambela sand and 20% Yedi sand with 80% Chewaka sand reduce the level of silt and clay to 6% .

Finally it is concluded that the compressive strength and the workability of the concrete are indirectly proportional to the amount of silt and clay in the fine aggregate. Any increment of this finer material decreases the strength and workability of the concrete. The workability and compressive strength of concrete can be maintained by washing the sand or by adding extra cement and by blending with quality sand so that for sand containing silt and clay below 10%, it is more economical to use cement increment method and for sand containing silt and clay above 10% ,it is more economical to use washing method.

Keywords: - silt and clay, cement increment, washing, compressive strength, workability.

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ACRONYMS

ACI- American concrete institute

ASTM- American society for testing and materials

BS- British standards

ES- Ethiopian standard

FM- fineness modulus

B/N- between

kg- kilogram

Kg/m3- kilogram per meter cube

Mpa- mega Pascal

W/c- water cement ratio

%- percentage

C-25 - 25 mega Pascal concrete strength

µm- micrometer

^{o}c- degree Celsius

Silt/clay- silt or clay

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CHAPTER ONE

1. INTRODUCTION

1.1. Back ground

Concrete is a construction materials which consists of the mixture of fine aggregates, coarse aggregates, cement and water which is mixed in a predetermined mix proportion. The fundamental requirement for making concrete structures is to produce good quality concrete. The quality of good concrete is dependent mainly on the quality of its constituent materials. Particularly the fine aggregate is the one of main constituents of concrete and it can be classified as natural aggregates and artificial aggregates **[1]**.

Natural sand is mainly excavated from river beds and always contains high percentages of inorganic materials like, silt and clay. The presence of any of these unwanted materials could slow down the hydration process thereby affecting the overall performance of concrete [**21]**.

Silt and cay materials are fine aggregate particles smaller than the 75μm (No. 200) sieve size. It is the type of fine materials found in river sand comprising particles smaller than 60μm that are reduced because of the natural processes of weathering **[2].** It is generally silt is a materials between 0.06 mm and 0.002 mm while Clay are materials less than 0.002 mm particle size and they are difficult to remove from the aggregate surface **[3, 4].**

If Silt and fine dust present in excessive amount, it increases the surface area of the aggregate and hence the amount of water required to wet all particles in the mix, thereby reducing the strength and durability of concrete. The water absorbed in the silt and clay does not contribute for hydration process. And also as silt and clay content increases, the bond between cement and aggregate particles reduces and the nature of interface between the aggregate and cement reduces, too **[5].**

As the percentage of silt and clay increase in the mix, the amount of cement required to neutralize the effect of silt and clay and to maintain the compressive strength of concrete also increase. The higher the clay and silt content in sand, the higher cement dosage increment needed to maintain the compressive strength of concrete **[6].** So that it is recommended carrying out a comparative cost analysis between the cement dosages increments used for sand with a particular clay and silt content, and washing the sand to reduce the clay and silt content, so as to determine which is more cost-effective to maintain the required compressive strength **[6].**

Therefore quality of constituent materials used in the preparation of concrete plays a paramount role on compressive strength of concrete. Water, cement, fine aggregates, coarse aggregates and any admixtures used should be free from harmful impurities that negatively impact on the properties of hardened concrete [**7]**.

ASTM C33 have set a limit on the maximum amount of materials passing through the 75μm mesh sieve that cannot exceed 5% for fine aggregate that used for concrete production. BS 882 and IS standard give a limit of 4%. Ethiopian standard limits silt and clay content up to 6%. Fine aggregate containing more than the allowable percentage of silt should be washed so as to bring the silt content to within allowable limits.

Therefore, this research has investigated the effects of silt and clay on concrete property such as: workability and compressive strength by identifying the level of silt and clay content of the locally available sand. Three basic methods were considered in the study which the effect of silt and clay content of sand on the compressive strength of concrete can be controlled. These are by washing the sand free of silt and clay or by adding some extra percentage of cement to neutralize the effect of the clay and silt content and or by blending with quality sand that has silt and clay below the specified limit on the standard. Since the mitigation of the silt and content of sand on concrete strength comes with extra cost, there is need to determine this cost in other to be able to build cost effective and safe structures.

1.2. Statement of the problem

The fundamental requirement of a concrete mix is that it should be satisfactory both in the fresh as well as in the hardened state, possessing certain minimum desirable properties like strength, workability and durability. Besides these requirements it is essential that the concrete mix is prepared as economically as possible. Impurities like silt and clay in natural sands contribute to reduced compressive strength, the higher the percentage of clay and silt content in sand used in concrete production, the lower the compressive strength of the hardened concrete **[9]**.

This strength reduction is due to Particles of clay will be incorporated into the matrix of the cement paste and affect hydration reactions. The other fraction of the coating will remain on the aggregate surface and influence the adhesion of the cement paste to the aggregates **[10]**. But there is no standards to indicate an optimum increment of cement with proportion to silt and clay to be applied for mitigation of the effect of this silt and clay content of sand.

In developing country like Ethiopia, due to rapid infrastructural growth the demand for natural sand is very high. Especially, in Jimma town there are a lot of civil works taking place such as Hotels, Mixed used buildings, Hospital, Stadium, Hall building etc. However, in Jimma, there is a problem in availability of good quality sand to be used in construction. It should be transported from long distances like from Gambela ,Werabe and Chewaka. Due to the high cost of transportation, Moving construction sand to the market increases the sale price of the market significantly. Therefore there should be a means how to use the locally available sand so as to minimize the transportation cost.

Therefore this research aimed at maintaining the required workability and compressive strength of concrete by mitigating the effect of silt and clay after identifying the level of silt and clay content of local sand and its effect on workability and compressive strength of concrete. In the study three methods were used to mitigate the effect of silt and clay. These are washing the sand to make free of silt and clay, adding extra cement to neutralize the effect and blending with quality sand to reduce the level of silt and clay content. And also since mitigation of silt and clay content of sand on concrete strength comes with extra cost, there is a need to determine this cost to build economical and safe structures.

1.3. Objective

1.3.1 General objective:-.

To mitigate the effect of silt and clay content of sands with a minimum cost so as to maintain the fresh and hardened properties of concrete.

1.3.2 Specific Objective

- To determine the level of silt and clay content and impurities present in building sand being supplied to Jimma.
- To determine the effect of silt and clay to the workability and compressive strength of concrete.
- To maintain the required workability and compressive strength of concrete by washing the sand, adding extra cement and blending with quality sand.
- To compare the result of the above mitigation methods and recommend the minimum cost of concrete production by including the extra cost for mitigation.

1.4. Research Question

1 What is the level of silt and clay contents of sand being supplied to jimma town?

2 What will be the effect of silt and clay on fresh and hardened property of concrete?

3 How can the required strength will be maintained by using this locally available sand having silt and clay above Ethiopian standard?

4 How silt and clay content of sand will affect the cost of concrete production?

1.5. Significance of the Study

The significance of the study was to produce durable and cost effective concrete by mitigating the effect of silt and clay content of sand and to indicate the minimum mitigation cost of the effect of silt and clay content of sand on compressive strength. Besides, the City Administration of Jimma, Owners, contractors and consultants will benefit from the study as a source of information that can help to improve and control qualities of the materials in addition to standard and specifications. And also other researchers will use the findings as a reference for further researches.

1.6. Justification

The rationale for conducting this study was providing the bench marks on how to mitigate the effect of silt and clay with a minimum cost under which the required strength of concrete can be maintained. Owing to the fact that now a days Jimma town is one of the developing town that undertaking various building and infrastructure project . But in this town, there are quality sand availability problem. So that for most of the construction under taken in the city , the quality sand that come from Gambela, Chewaka and Werabe is recommended which is far from the town. So that the transportation cost of the sand increase the cost of concrete production. In Jimma zone there are sites for obtaining Natural sand like Asendabo ,Yedi and Nada but this naturally existing fine aggregate may not exist in a pure state . it contain very fine particles such as dust, silt and clay that adversely affecting the strength and durability of concrete and reinforcing steel there by reducing the life of structure. Therefore it needs to reduce the effect of these impurities on strength and workability of concrete and to produce a cost effective concrete by using locally available sand.

1.7. Scope and Limitation.

This research was conducted using natural river sand from 6 main supply point to Jimma and the result of the study was restricted to this particular sites. It only concentrates on the effect of silt and clay content of sand on workability and compressive strength of concrete.

A concrete mix having high cement may give rise to excessive cracking caused by differential thermal stress due to hydration of cement. For high strength concrete, increasing cement content beyond certain value, of the order of 550kg/m3 or so, may not increase the compressive strength. From these considerations as well as those of overall economy, the maximum cement content in the concrete mix was limited to 530kg/m3 as stated by EBCS2, 1995 .Therefore Due to the adverse effect of cement ,this research is limited to C-25 concrete because as the strength of concrete increase the amount of cement required also increase so that the extra cement added to mitigate the strength reduction due to silt and clay may cause shrinkage and thermal cracking that reduce the durability of the concrete .

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Introduction

Concrete is basically a mixture of two components: aggregates and paste. The paste, comprised of Portland cement and water, binds the aggregates (usually sand and gravel or crushed stone) into a rocklike mass as the paste hardens because of the chemical reaction of the cement and water. Supplementary cementations materials and chemical admixtures may also be included in the paste **[11].**

Quality of constituent materials used in the preparation of concrete plays a paramount role on compressive strength of concrete. Water, cement, fine aggregates, coarse aggregates and any admixtures used should be free from harmful impurities that negatively impact on the properties of fresh and hardened concrete **[7].**

2.2. Aggregate

Aggregates are the materials basically used as filler with binding material in the production of concrete and provide concrete with better dimensional stability and wear resistance. They are derived naturally from igneous, sedimentary and metamorphic rocks or manufactured from blast furnace slag, etc.**.** Therefore it is important to obtain right type and quality of aggregates (fine and coarse). Because aggregates occupy 60% to 75% of the concrete volume (70% to 85% by mass) and strongly influence the concrete's freshly mixed and hardened properties, mixture proportions, and economy **[12].** So that to proportion suitable concrete mixes, certain properties of aggregate which influence the paste requirement of fresh concrete such as shape and texture, size graduation, moisture content, specific gravity and bulk unit weight must be known **[11]**.

Aggregates give concrete volumetric stability and provide similar thermal expansion properties to steel, allowing for steel reinforced concrete to function effectively as a composite. Cement paste alone would not allow for this property. Furthermore, aggregates significantly reduce moisture related deformations in concrete. Concrete typically exhibits shrinkage of 10 to 15 per cent of that of pure cement paste. They restrain creep and thereby reduce long-term concrete deformation. They generally improve the strength and stiffness of concrete and provide necessary rigidity. They provide wear resistance as well as traction for concrete in applications subjected to traffic. As aggregates tend to be the most durable material in concrete, they typically improve concrete durability **[13]**.

As per ACI E-701, Aggregate is granular material such as sand, gravel, crushed stone, blast-furnace slag, and lightweight aggregates. Aggregate properties significantly affect the workability of plastic concrete and also the durability, strength, thermal properties, and density of hardened concrete. Furthermore the quality of aggregate is considerably important because at least three-quarters of the volume of concrete is occupied by it **[2]**. This indicates that it is impossible to get good quality concrete without good quality aggregates. Aggregate has both economic and technical advantages in making concrete. .

In choosing aggregate for use in a particular concrete, attention should be given to the following three important requirements **[14]**.

1) Workability, the size and gradation content of the aggregate should be such that unnecessary labor will not be required in mixing and placing.

2) Strength and durability when hardened for which the aggregate should be:

   a) Be stronger than the required concrete strength.
   b) Contain no impurities which adversely affect strength and durability.
   c) Shouldn't go in to undesirable reaction with the cement.
   d) Be resistant to weathering action.

3) Economy of the mixture –meaning to say that the aggregate should be:

   a) Available from local and easily accessible deposit or quarry.

   b) Well graded in order to minimize paste hence cement requirement.

Generally aggregates have three basic functions such as to provide a relatively cheap filler for the cementing material, to provide a mass of particles that are suitable for resisting the action of applied loads, abrasion, the percolation of moisture, and the action of weather; and to reduce the volume changes resulting from the setting and hardening process and from moisture changes in the cement-water paste [14].

2.2.1. Classification of Aggregates

According to ACI E1-07 Aggregates may be broadly classified as natural or artificial, both with respect to source and to method of preparation. Natural sands and gravels are the product of weathering and the action of wind or water, while manufactured crushed fine aggregate and crushed stone coarse and fine aggregate are produced by crushing natural stone. Crushing, screening, and washing may be used to process aggregates from either sand and gravel deposits or stone quarries. Synthetic aggregates may be either by products of an industrial process, in the case of blast-furnace slag, or products of processes developed to manufacture aggregates with special properties, as in the case of expanded clay, shale, or slate used for lightweight aggregates.

It has been understood from different literatures that aggregates can further be classified based on different basis. The most commonly used classifications are based on size as coarse and fine; mineralogy and petrography as Igneous, Metamorphic and Sedimentary; chemical composition as Argillaceous, Siliceous and Calcareous; weight as heavy, normal and light; source as natural and artificial; and finally based on particle size and shape. The last one is the most frequently used classification. Based on this classification, this research generally focuses only on the natural type of fine aggregates. On this basis, one can distinguish between fine aggregates, consisting mostly of small particles, and coarse aggregates, consisting mostly of large particles **[15]**. Fine aggregates often called sand according to BS 882 are of size not larger than 5mm and that of coarse aggregate is with size at least 5mm, in addition to this according to ASTM E11 the fine aggregates are those with particles smaller than 4.75mm with regard to the physical properties of aggregates. These materials can be particularly effective at altering and modifying the concrete microstructure **[13]**.

2.2.1.1. Natural River Sand

Natural River sand: - is fine aggregate from the natural disintegration of rock and which has been deposit by streams or glacial agencies. It can be got from various source, river, run off, sand deposit etc. and always contains high percentages of inorganic materials, chlorides, sulphates, silt and clay that adversely affect the strength and durability of concrete and reinforcing steel thereby by reducing the life of structure [**4]**. The high percentages of sand in hardened concrete have an impact the strength and cost effectiveness of the concrete. That is why the materials for construction should be sampled, inspected, tested and acceptance for use or be given if they meet the established standards in all respects. Fine aggregates such as sand used in concrete production may contain excessive silt and clayey contents as well as organic impurities that impact negatively on the quality of hardened concrete.

Being an important component for concrete, obtaining good quality natural sand is critical. These easily available natural resources usually accompany gravels which basically imply the deposits may not have been laid uniformly, meaning a potential change in quality and size is possible. In some deposits, sand found below the water table differs in fines content and quality from that found above the water table, due to this subsurface drilling, sampling, and testing are necessary to know to what degree and where these differences occur **[16]**.

To prevent buildings failure (Collapse of buildings), careful selection of construction materials like building sands have paramount role to ensure that they meet the required construction standards. Impurities in sand impact negatively on compressive strength as well as bond strength between steel reinforcement and concrete and may cause buildings failure **[4]**. BS 882 stated that aggregates for making concrete should be free of all sorts of impurities.

Use of good quality building sands improve both operational and life-cycle performance of buildings by preventing frequent repairs and ensuring building’s long lifespan thus reducing overall investment cost **[4]**.

Therefore concrete designers must provide adequate factor of safety to guard against structural failure as a result of these impurities in building sand. Frequent testing of sand for construction purposes is highly recommended to ensure measures are put in place e.g. washing of sand in a bid to prevent collapse of buildings as a result of excessive levels of silt and clay content and organic impurities [**4**]. It is very important to control the quality of the aggregate to be used in concrete making. Most importantly, the effect of the silt and clay content of sand on the compressive strength of concrete must be controlled **[6]**. There are two basic methods by which the effect of silt and clay content of sand on the compressive strength of concrete can be controlled. These are by washing the sand free of silt and clay or by adding some extra percentage of cement to neutralize the effect of the silt and clay content [2006]. But the most common method to remove the amounts of these fine particles of sand is washing with water [**16].** Standard Test Method in order to determine the Materials Finer than 75μm (Micro-finer), by wet sieving was used [**17**]. This test method covers determination of the amount of material finer than a 75μm (#200) sieve in aggregate by washing. Clay particles and other aggregate particles that are dispersed by wash water, as well as water-soluble material, could be removed from the aggregate during the test.

2.2.1.1.1. Quality of Natural River Fine Aggregate

Naturally existing material fine aggregate may not exist in a pure which means consist of some impurities. Impurities can be classified as solid materials or soluble substances. Solid materials are generally present in a very finely divided state, passing the 75-μm sieve. Such material will appreciably increase the water requirements for workable concrete and reduce the abrasion resistance of hardened concrete if present in large amounts. The fine fraction is also likely to stick to the surfaces of the large aggregate particles, isolating those particles from the surrounding concrete and causing a reduction in strength. Materials in this class are commonly silt, clay, rock dust, and organic matter **[18]**.

Quality assurance of building materials is very essential in order to build strong, durable and cost effective structures **[8]**. Impurities in building sands contribute to reduced compressive strength as well as bond strength between steel reinforcement and concrete and may cause buildings failure. The higher the percentage of clay and silt content in sand used in concrete production, the lower the compressive strength of the hardened concrete **[9]**. The maximum content of silt and clay in sand as 6%, beyond which sand is regarded as unsuitable for construction work [**19**]. American Society for Testing and Materials construction standards give an allowable limit of 5% for silt and clay content in sand [**20**]. On the other hand British standard states that the percentage of clay and fine silts must not exceed 4% by weight for sand for use in concrete production **[21]**.

2.3. Definition of Silt and Clay

Silt is generally considered to be materials between 0.06 mm and 0.002 mm while Clay is materials less than 0.002 mm particle size **[3]**.silt and clay is the type of fine materials found in river sand comprising particles smaller than 60μm that are reduced because of the natural processes of weathering **[2]**.Silt and clay is not as strong as typical fine aggregates. Silt and clay is always attached to the aggregate surface and is difficult to discard.

2.4. Effect of Silt and Clay on Workability and Compressive Strength of Concrete

The compressive strength of concrete is decreased with the increase of clay and silt content of sand. This strength reduction is due to Particles of clay will be incorporated into the matrix of the cement paste and affect hydration reactions. The other fraction of the coating will remain on the aggregate surface and influence the adhesion of the cement paste to the aggregates. They can absorb water and their properties can change. And also decreasing in mixing water will reduce the workability of the concrete **[10]**.

The water absorbed in the silt and clay does not contribute for hydration process. And also as silt content increases, the bond between cement and aggregate particles reduces and the nature of interface between the aggregate and cement reduces, too. And also the small size of silt and clay combined with large surface area may increase the amount of water used in the concrete mix design. Conversely, the chemically reactive nature of silt and clay may also affect the properties of the interface between the cement pastes and aggregate **[22]**.

Silt and clay will interfere with the bonding of aggregates to cement.. If the silt and clay comes in contact with water in air voids, it can shrink or swell, either building internal pressure (swelling) or leaving larger voids and weakening the concrete (shrinking) **[4].**

Depending on the nature of the swelling in these clays we can envision two different scenarios upon adding the cement powder to the mixture: The dispersed clay has the ability of crystalline swelling. Clayey silt particles will absorb significant amounts of the mixing water of the mixture leaving a quantity of available water that will yield mixing water smaller than the best possible for hydrating the cement powder.

The dispersion of these clays gives way to an aqueous suspension having a large number of very anisotropic Nano-particles. Thus, the viscosity of the water of the mixture in these systems is expected to increase. These thin-layer particles may coat the anhydrate cement compounds added to the concrete mixture and affect the kinetics of hydration. This may have an effect on the physical properties of the resulting concrete **[23]**.

Impurities in sand impact negatively on compressive strength as well as bond strength between steel reinforcement and concrete and may cause buildings failure [**4**]. The higher percentage of clay and silt content in sand used in concrete production, lower the compressive strength of the hardened concrete **[9]**. If Silt and fine dust, present in excessive amount, increases the surface area of the aggregate and hence the amount of water required to wet all particles in the mix, thereby reducing the strength and durability of concrete [**5**]. The higher the clay and silt content in sand, the higher cement dosage increment needed to maintain the compressive strength of concrete [**6**]. Therefore it is recommended to carry out a comparative cost analysis between the cement dosages increments used for sand with a particular silt and clay content, and washing the sand to reduce the silt and clay content, so as to determine which is more cost-effective to maintain the required compressive strength **[6]**.

fine aggregates with excess fines tend to cause the concrete to be sticky and consequently reduce the concrete's workability **[24].** A concrete made by sand having silt and clay content of up to 6% gives a satisfactory result related to the target strength **[25]**.

2.5. Limiting Value of Silt and Clay Content of Sand Set By Different Standard

Aggregates in particular those derived from certain types of river sand are not only is gap-graded, but also contain high levels of fine materials. A limit on the maximum amount of materials passing through the 75μm mesh sieve cannot exceed 5% for fine aggregate that used for concrete production [**20**]. BS 882 and IS standard give a limit of 4%. Ethiopian standard limits silt content up to 6%. Fine aggregate containing more than the allowable percentage of silt should be washed so as to bring the silt content to within allowable limits.

2.6. Method of mitigation

2.6.1. Washing

Fine aggregate containing more than the allowable percentage of silt should be washed so as to bring the silt content to within allowable limits. If a limit on the maximum amount of materials passing through the 75μm mesh sieve exceed 5% for fine aggregate that used for concrete production [**20**]. BS 882 and IS standard give a limit of 4%. Ethiopian standard limits silt content up to 6%. And recommend that For sand containing silt and clay above the limit, it has to be washed to bring the level of silt below the standard[**19**].

2.6.2. Cement increment.

Cement in general can be described as a material with adhesive and cohesive properties which makes it capable of bonding mineral fragments in to a hard continuous compact mass **[2, 5**].Though there are various types of cement used for concrete production, Portland cement is one which is commonly used in Jimma.

cement content in the mixture above the optimum value does not contribute to greater strength than the required design strength. In addition the high cement content will Couse the concrete to become sticky as well as have shrinkage and cracking problem **[26].** But if the sand in the concrete mixture contains high percentage of silt and clay, it decreases the compressive strength and the workability of concrete. The strength reduction is due to the particle of silt and clay will be incorporated in to the matrix of the cement paste and affect the hydration reaction. The other fraction of the coating will remain on the aggregate surface and influence the adhesion of the cement paste to the aggregate. And also due to the larger surface area, the excessive fine material will absorb the mixing water so that it reduce the workability of concrete [**10**].The higher the clay and silt content in sand, the higher the cement increment needed to maintain the compressive strength of concrete[**6]**.

2.6.3. Blending

Blending of aggregate from two or more source would be required to satisfy the specification. The reason for blending of aggregate include to obtain desirable gradation, when single natural material is not enough and when economy is considered. And also Blending high silt content with low silt content will reduce the level of silt and clay.

2.7. Physical Properties of Aggregate

Most properties of aggregate depends on the properties of parent rock e.g. chemical and mineral composition, petrographic classification, specific gravity, hardness, strength, physical and chemical stability, pore structure, color, etc. in addition, there are properties of aggregate absent in the parent rock: particle shape and size, surface texture and moisture content. All properties may have a considerable influence on the quality of fresh or hardened concrete [**2**]. Among these properties for this thesis only focus such as aggregate graduation, moisture content, specific gravity and bulk unit weight are important to proportion suitable concrete mixes.

The properties of an aggregate to be considered while during selection of aggregate for concrete works are grading, shape, texture, specific gravity, bulk density, voids, porosity, moisture content, bulking and strength [**12**].Those properties of aggregate affects significantly the resulting concrete quality produced as briefly explained under.

2.7.1. Fine-Aggregate Grading

The most desirable fine-aggregate grading depends on the type of work, the fruitfulness of the mixture, and the maximum size of coarse aggregate. In leaner mixtures, or when small-size coarse aggregates are used, a grading that approaches the maximum recommended percentage passing each sieve is desirable for workability. In general, if the water-cement ratio is kept constant and the ratio of fine-to-coarse aggregate is chosen correctly, a wide range in grading can be used without measurable effect on strength. However, the best economy will sometimes be achieved by adjusting the concrete mixture to suit the gradation of the local aggregates [**11**].

Fine aggregate grading has a greater effect on workability of concrete than coarse aggregates. Manufactured sands require more fines than natural sands to achieve the same level of workability, probably due to the angularity of the manufactured sands particles [**4]**.

The workability and cohesiveness of a fresh concrete are strongly dependent on aggregate grading. Thus, provided other constituents are correctly proportioned, appropriate selection of aggregate grading will give a concrete that is easily compacted and, given suitable curing, is ultimately a dense concrete of good strength and durability [**13**].

Variations in grading can seriously affect the uniformity of concrete from batch to batch. Very fine sands are often uneconomical; very coarse sands and coarse aggregate can produce harsh, unworkable mixtures [**11**].

Table 2. 1 ASTM grading requirement for fine aggregate

Sieves Size	ASTM No.	Cumulative Percentage passing
9.5mm	3/4 in	100
4.75mm	3/16in	95-100
2.36mm	8	80-100
1.18mm	16	50-85
600 µm	30	25-60
300 µm	50	10-30
150 µm	100	2-10

2.7.1.1. Fineness Modulus

Using the sieve analysis results, a numerical index called the fineness modulus (FM) is often computed. The FM is the sum of the total percentages coarser than each of a specified series of sieves, divided by 100.

$finenes\ modulis = \sum(cumulative\ \ \%\ retain)/100$……………………………….equation 2.1

The specified sieves are 75.0, 37.5, 19.0, and 9.5 mm (3, 1.5, 3/4, and 3/8 in.) and 4.75 mm, 2.36 mm, 1.18 mm, 600µm, 300 µm, and 150 µm (No. 4, 8, 16, 30, 50, and 100).

Note that the lower limit of the specified series of sieves is the 150 µm (No. 100) sieve and that the actual size of the openings in each larger sieve is twice that of the sieve below. The coarser aggregate size, the higher the FM. for fine aggregate used in concrete, the FM generally ranges from 2.0 to 3.3 as per defined ACI E-701 and According to Ethiopian Standards ES C. D3. 201 the fineness modulus of fine aggregate in the range of 2.0-3.5 with tolerance of ±0.2. It is used as an index to the fineness or coarseness and uniformity of aggregate supplied, but it is not an indication of grading since there could be an infinite number of grading which will produce a given fineness modulus. The following limits may be taken as guidance [**14]**.

Table 2. 2 Limitation of fineness modulus for different sand category

Category of sand	Fineness modulus(FM) limit of sand
Fine sand	2.2-2.6
Medium sand	2.6-2.9
Coarse sand	2.9-3.2

Sand having a fineness modulus more than 3.2 will be unsuitable for making satisfactory concrete (Denamo, 2005). However, it is clear that one parameter, the average, cannot be representative of a distribution: thus the same fineness modulus can represent an infinite number of totally different size distributions or grading curves. The fineness modulus cannot, therefore, be used as a description of a grading of an aggregate but it is valuable for measuring slight variations in the aggregate from the same source that is as a day to day check **[2]**.

2.8. CEMENT PASTE

Cement paste is the binder in concrete or mortar that holds the fine aggregate, coarse aggregate, or other constituent's together in a hardened mass. The properties of concrete depend on the quantities and qualities of its constituents. Cement is the most active component of concrete and usually has the greatest unit cost, its selection and proper use are important in obtaining most economical concrete mixture. Most cement will provide adequate levels of strength and durability for general use.

High cement content in a mixture does not contribute to greater strength than the required design strength. In addition, the high cement content will cause the concrete to become sticky as well as have shrinkage and cracking problems [**27**]. Therefore, cement content should be balanced to achieve performance while minimizing risk of these problems. This thesis investigates how much additional cement content is needed to neutralize the effect of silt and clay to achieve the desired strength, durability and workability requirements in a concrete mixture through laboratory testing and compare with washing of sand to make free of silt and clay. The American

Concrete Institute (ACI) 211 Report (2002) was used as a reference to determine the applicability and significance of the suggested cement content.

2.8.1. Hydration of Portland cement

Hydration of Portland cement is the chemical reaction it undergoes when brought in contact with water. However, unlike the reaction of the other calcareous cements, hydration of Portland cement is a far more complex phenomenon. This is so because Portland cement is a heterogeneous mixture of several chemical compounds, which are complex in themselves

[27].

For a given w/c, workability decreases as cement content (paste content) decreases, because of having insufficient paste to lubricate the aggregates. This is more pronounced for mixtures with low w/c mixtures that have lower water per unit paste contents. For given cement content, increasing w/c improves workability because there is more paste to lubricate the aggregates in mixtures. For a given w/c, as cement content decreases, overall setting time increases because in mixtures containing low cement content, there is not sufficient paste to glue together the aggregate particles. For a given cement content, decreasing w/c reduces setting time because in mixtures with lower w/c (and lower paste content) cement grains are closer to each other thereby providing a high probability of the hydration products becoming interconnected. This interconnection tends to cause stiffness while reducing the setting time. In addition, to make the findings independent of the selected aggregate system, the relationship between paste volume and concrete properties was established. In order to meet the desired workability, strength and durability requirements; the paste volume should be within the range of 160% to 170% of the volume of voids. Exceeding this range will adversely affect the concrete performance by decreasing strength, chloride penetration and air permeability [**28**]. For a given w/c, both drying and autogenous shrinkage increase with increasing cement content [**11**].

2.9. Concrete property

2.9.1. Workability

American Concrete Institute (ACI) 116R defines workability as “that property of freshly mixed concrete or mortar that determines the ease and homogeneity with which it can be mixed, placed, compacted and finished to a homogenous condition”. Workability can be identified by three main parameters [**11**].

cohesiveness: the resistance to segregation,

consistency: the ease of flow, and

plasticity: the ease of molding.

Workability is commonly assessed by engineers using the slump test [**29**]. As silt and clay content of the sand increase , the workability of the concrete decrease because of silt and clay absorb the mixing water [**10**]. For given water content, decreasing cement content will produce stiff mixtures with low workability. Concrete with high cement content shows high Cohesiveness but becomes sticky [**11**].for a given w/c ratio workability decreases as the cement content decreases because of having insufficient paste to lubricate the aggregate [**28**].

2.9.2. Compressive Strength of Concrete

The strength of a material is defined as the capability of the material to resist stress without failure [**24**].The strength of hardened concrete is fundamental in structural design, and is widely used as an index to predict other concrete properties.

The compressive strength of concrete is one of the most important and useful properties of concrete. The primary purpose for design concrete is to resist compressive strength in structural members, in general is the characteristic material value for classification of concrete.

Strength of concrete is the commonly considered its most valuable property, although in many practical cases other characteristic ,such as durability and impermeability , may in fact be more. However, strength usually gives an overall picture of the quality of concrete because strength is directly related to the structure of the hardened cement paste [**2**]. In addition, it has a great practical and economic significance because the sections and sizes of the concrete structures are determined by it.

In addition to this, Strength is usually the basis for acceptance or rejection of the concrete in the structure. The specifications or code designate the strength (nearly always compressive) required of the concrete in the several parts of the structure. Because concrete is an excellent material for resisting compressive loading, it is used in dams, foundations , columns, arches and tunnel linings where the principal loading is in compression .

Strength is most of the time determined by means of test either cylinders and cubic test made of fresh concrete on the job and tested in compression at various ages. The requirement is certain strength at an age of 28 days or such earlier age as the concrete is to receive its full service load or maximum stress

Therefore, it is important to this work that mitigating the effect of silt and clay content of sand have on the strength of concrete been investigated.

2.9.2.1. Factors that affect the strength of concrete

There are a multitude of variables that affect the strength of concrete. The factors that are likely to influence the strength of concrete are porosity, aggregate and aggregate paste interface[**24**].

The interface between the aggregate and the concrete has been found to be the weakest area in the concrete matrix . A number of factors influence the strength of the aggregate-paste interface and therefore the overall strength of concrete [**24**].

- *Water-to-cement ratio*: It has been found that at lower water-to-cement ratios, the strength of the aggregate-paste interface increases.
- *Age of concrete:* The strength of the aggregate-paste interface has been found to increase with age, provided there is sufficient water.
- *Bleeding:* Strength decreases with increased bleeding
- Type of cementitious material: Materials containing very fine particles develop stronger aggregate-paste bonds due to the fine filler effect.

• *Ultra-fines in aggregates*: It has been found that ultrafine material reduces bleeding and causes a fine filler effect at the aggregate-paste interface. Both of these effects will increase the strength of concrete.

• *Surface texture of aggregates:* Strength has been found to increase with increasing roughness of aggregates.

2.9.2.2. Compressive strength test of concrete

Test can be made for different purpose but the main two objectives of tests are control of quality and compliance with specification [**2**]. Compressive strength of concrete**:** Out of many test applied to the concrete, this is the ultimate important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not .For cube test two types of specimens either cubes of 15 cm X 15 cm X 15 cm or 10cm X 10 cm x 10 cm depending upon the size of aggregate are used. For most of the works cubical molds of size 15 cm x 15cm x 15 cm are commonly used. The concrete is poured in the mold and tempered properly so as not to have any voids. After 24 hours these molds are removed and test specimens are put in water for curing. The top surface of these specimens should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen. These specimens are tested by compression testing machine after 7 days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete [**30**].

Generally the Slit and Clay content has been found to influence the strength of concrete. As silt and clay content increase, the workability and strength of concrete decrease. It is suggested that the reduction in strength is due to the low aggregate past bondage of concrete and incomplete hydration reaction. Therefore, three basic methods have been considered in the study which the effect of silt and clay content of sand on the compressive strength of concrete can be controlled. These are by washing the sand free of silt and clay or by adding some extra percentage of cement to neutralize the effect of the clay and silt content and or by blending with quality sand that has silt and clay below the specified limit on the standard.

CHAPTER THREE

3. RESEARCH METHODOLOGY AND MATERIAL

This chapter focuses on over all methodology and material used in conducting the research .it includes the experimental investigations, mix proportioning and method of analysis.

In order to obtain the final results Laboratory experimentations have been carried out. First concrete making materials preparation and testing have been performed. Then, based on the test results concrete making materials proportioning have been executed and mix-design was prepared for C-25 concrete grades. After that, concrete sample preparations at different Percentage of Silt and Clay content and with original and washed sand sample have been performed. And also for each percent of silt and clay, a three trial of cement increment was applied and a concrete sample have been prepared. Then, the prepared concrete samples have been tested for both in the fresh and hardened states. For the fresh state workability property of concrete has been checked and for hardened state, concrete compressive strength tests have been carried out at age of 7^{th} and 28^{th} days.

The results obtained from experiment are discussed and presented in tables and figures. Finally, conclusions are drawn and recommendations have been forwarded.

3.1. Study area

The study was conducted at Oromia regional state of Jimma zone, southwestern Ethiopia which is located 346 km by road southwest of Addis Ababa. Its geographical coordinates are between 7° 13’- 8° 56N latitude and 35°49’-38°38’E longitude with an estimated area of 19,506.24. The town is found in an area of average altitude, of about 5400 ft. (1780 m) above sea level.

3.2. Study period

The study was conducted from April 2017 to October 2017.

3.3. Research Design

The research study was conducted by laboratory Experimental design. Quantitative study was applied in the research. Comparative experimental and analytical method were used during the study in order to provide the most reliable and economical mitigation methods by investigating the silt and clay content of natural fine aggregate and identifying their effect on concrete properties such as workability and compressive strength of concrete.

3.4. Study procedure

The following procedures were used while conducting the research.

- Reviewing all related literature which include articles, research paper ,books, standards like ES, ASTM, BS
- Sample collection and preparation
- Laboratory test for determining the physical property of concrete making material
- Concrete mix design and proportioning
- Concrete production process
- Compressive strength test
- Result analysis and discussion.
- Conclusion and recommendation.

3.5. Study variables.

- **Independent variable:-** Workability and compressive strength of concrete.
- **Dependent variable: -** Silt and clay content of sand

3.6. Data collection process

The researcher went to sand extraction site and took sample based on his knowledge and judgment.

Figure 3. 1 Collecting representative sample from extraction site(river)

3.7. Materials

The material used for this experimental research is:-

Cement: - Type of Cement used in the concrete mix was Derba - Ordinary Portland cement (OPC) whose Cement Grade 42.5R which is locally available cement.

Coarse aggregate: - crushed granite rock, with maximum size of 25mm was collected from local manufacturing unit in jimma town. For all experiment a single types of course aggregate was used.

Sand: - The sand was collected from six sand supply point . these were Asendabo, Nada, Yedi Werabe Gambela and Chewaka , the former three site are located in Jimma zone around asendabo which is 54km from the town and the later three site are located out of jimma zone.

Water: - the water used for this research was potable water which is free from any impurities.

3.7.1. Material preparation

Coarse aggregate;- Coarse aggregate sample was washed before using for concrete mix and sun dried on a clean platform. After the coarse aggregate sample was surface dried then the sample was prepared to the laboratory experimental test by using Sample Splitter as shown on figure below

Figure 3. 2 preparing coarse aggregate sample for laboratory test by using sample splitter.

Fine aggregate;- All sand sample were air dried to reduce the moisture content before the commencement of the laboratory test. Half of the sand sample selected for the study was washed with potable water by using 75µm sieve in order to free of clay/silt content and sun dried on a clean platform. As shown in fig 3.3

Figure 3. 3 washing of sand to make free of silt and clay.

In washing the sand, the time and the amount of water needed to wash specific volume of sand was determined so that the time taken to wash 20 kg of sand having silt and clay of 18% was recorded as 34 min and the amount of water required to wash this sand until the level of silt and clay reduced to 0.94% was 80 litter.

3.8. Experimental investigation

It's obvious that, concrete can be produced simply through mixing of concrete ingredients, but the important point is producing acceptable quality concrete with a reasonable economy. To produce acceptable quality, it's important to make physical characteristic tests on materials before any concrete experiments are carryout. So, this chapter elaborates the general properties of the materials used in the production of concrete for the research and their physical test results conducted from the experiment. And also mix design and materials proportioning, concrete mixing and production process, casting, curing and finally compressive strength testing of the concrete cubes were carried out.

3.8.1. Silt and clay content.

The silt and clay content of all sand sample were determined by wet sieve analysis method in the laboratory by taking 1 kg sample of fine aggregate and drying in an oven at 105 c^o for 24 hours. The material was weighed and its mass was found to be M1. It was then thoroughly washed on a 7 5 μm sieve until clear water comes and again dried in oven at 1 0 5 c^o for another 24 hours. Its final mass was then taken and it was found to be M2 The silt content is calculated by the following formula and the result is shown on the figure below. Silt content= M1-M2/M1*100

Figure 3. 4 Shows washing, wet sieving of sand on 75μm and oven dried sample.

3.8.2. Physical Property of aggregate.

In order to design and make a concrete mix, the aggregates properties had to be assessed. In order to do this a number of tests were carried out on the above materials. The performed test includes: sieve analysis, bulk and dry density, moisture content, absorption capacity, unit weight, etc. All of the aggregates tests were done in accordance with the Ethiopian standards and conforms to the ASTM requirements.

Table 3. 1 Physical property of coarse aggregate

specific gravity	water absorption	dray roded density	loose unit weight	moisture content
2.65	0.745%	1592kg/m3	1486kg/m3	0.20%

Table 3. 2 physical property of fine aggregate.

Sands	Fines modulus	specific gravity	water absorption	unit weight(kg/m3)	moisture content
Yedi	2.8502	2.55	2.02%	1540	1.10%
Asendabo	1.566	2.52	2.30%	1590	1.05%
Nada kela	3.394981722	2.64	1.86%	1525	1.20%
Werabe	3.3394	2.7	1.42%	1520	0.85%
Gambela	2.9776	2.65	1.56%	1530	0.97%
Chewaka	2.7686	2.6	1.76%	1562	1.00%

3.9. Preparation of specimen (cubes).

To know only the effect of silt and clay and to make the other factor constant a single type of sand was used having a silt/clay content of 18%. So that the material used to prepare the test specimen are natural fine aggregate of Yedi sand and coarse aggregate from local manufacturing unit.

A total of 102 specimens (cubes) were produced from this, 30 cubes were produced to determine the effect of silt /clay on concrete workability and strength and the rest 72 cubes were produced to maintain the required strength of concrete by adding cement with proportion to silt/clay content.

Five sample with varying silt and clay was taken and three cubes (of 150 x 150 x 150 mm3) for compressive strength at 7 and 28 days of curing time was made for each percentage of silt/ clay . The resultant samples of sand was labeled A to E. Sample A contained 0.94% silt and clay ; sample B contained 6% of silt and clay , sample C contained 10% silt/ clay, sample D contained 14% silt/clay and sample E contain 18% silt/clay . For 0.94% silt and clay (control sample) all of the sand was washed. For 6 % silt/clay 66.6% of the sand was washed. For 10% silt/clay, 44.4% of the sand was washed for 14% silt/clay 22% of the sand was washed. For 18% the quarry sand is used.

for maintaining the required strength , another four sample with silt/clay content having the same value to the above four sample except 0.94% was prepared and for each percent of silt/ clay, a three trial of cement increment was applied and a total of 72 cubes were prepared.

3.10. Concrete Mix Design and Materials Proportion.

In this research work, the ACI Method of concrete mix design was used to design C-25 concrete grade having 33.5 MPa target mean strength with 0.5 of water to cement ratio .In addition to this, the slump was 25 to 50mm. for this study, one mix-design was prepared for the original sand samples having 18% of silt/clay content (i.e. Yedi sand) . For all the concrete mixes, the same w/c ratio was used. The aim of this was to ensure that any variations in the properties of the concrete were because of silt/clay content of the sand. The detail of mix design was shown on appendix , annex-1

The quantity of concrete materials was calculated by using the physical properties of the materials and Table 3.4 show the quantity of materials for one cubic meter for C-25 concrete grade. The Standard cast iron molds of size 15x15x15cm are used in the preparation of concrete cubes for compressive strength tests.

Table 3. 3 show Mix proportioning of concrete.

Material	weight in (kg/m3)	weight in (kg) for 1 cube	weight in (kg) for 6 cubes	weight in (kg) for 102 cubes
cement	360	1.22	7.29	123.93
Sand	731.4	2.47	14.82	251.78
coarse aggregate	1064.5	3.59	21.55	366.45
Water	192.53	0.65	3.89	66.28

3.11. Concrete mixing and Production Process

The concrete molds and large flat plat were cleaned from all dust and the concrete molds coated with releasing agent (oil) to smooth the surface and to prevent sticking of mixed concrete with the mold. The ingredients, such as; cement, fine aggregate (sand), coarse aggregate and water were measured to an accuracy of 0.5g balance. After that the weighted coarse aggregate was first added on the large flat plat and the fine aggregate was added after the coarse aggregate and then the cement is added next to fine aggregate and dry mixed for a minute. Then, water was added to the dry mixed concrete ingredients mixture and thoroughly mixed by hand as shown on the Figure.3.5

Figure 3. 5 Concrete mixing process.

3.11.1. Check for workability

The mixed concrete was checked for workability by filling the standard slump cone with three layers by rodding each layer with 25 times according to ASTM C143 as shown in Figure. Between each mix, the tool was cleaned using tap water to ensure that there was no contamination between the mixes.

Figure 3. 6 Slump test.

3.11.2. Casting

After checked the slump the mixed concrete was placed in the mold and was well compacted in three layers with the help of a tape rode by rodding each layer with 25 times and as well as Side compaction of the molds was carried out by using tire hammer . For each mix, prepare 6 cubes molds having (150mmx150mmx150mm) size were cast for compressive strength.

3.11.3. De-molding and Curing

The concrete mix was casted in the molds for the first 24 hours. After that, the concrete was removed from the molds and placed in a water bath at a temperature of 22 ± 1^{o}C for curing to take place until the testing age was reached as shown in Figure

Figure 3. 7 Removing of concrete cube from the mold and immersion in to curing water.

3.12. Compressive strength testing of the concrete cubes.

After7 and 28 days curing period the concrete cubes specimens was removed from the water bath then placed in dry surface until the specimens was surface dried and then the concrete cubes specimens were weighted in order to determine the unit weight , Finally, the specimens was tested by compression testing machine as shown on the Figure below.

Figure 3. 8 surface draying, weighing and crushing of concrete cubes.

CHAPTER FOUR

4. RESULT AND DISCUSION

The first part of this chapter identifies the level of silt and clay content of sands collected from 6 main supply point to Jimma town and the second part deals with determination of the effect of silt and clay on fresh and hardened property of concrete and followed by mitigation of the effect of silt and clay by using three different methods and finally the analysis of row experimental data, result and discussion was performed.

4.1. Test for Silt and Clay Content

Standard Test Method in order to determine the Materials Finer than 75µm (Micro-finer), by wet sieving was used as specified by ASTM C117. This test method covers determination of the amount of material finer than a 75µm (#200) sieve in aggregate by washing. Clay particles and other aggregate particles that are dispersed by wash water, as well as water-soluble material, could be removed from the aggregate during the test. For this research six different sands are collected from different extraction site namely Asendabo, Nada ,Yedi Werabe Gambela and Chewaka and their silt content was determined. The result of this test showed that nada kela sand contain maximum amount of silt and clay which is 20% and the mimimum silt and clay content is obtained for gambela sand of 2.5%. whereas the silt and clay content of asendabo, Yedi, Werabe and Chewaka sand are 14%, 18%, 6% and 3% respectively. Generally the result of the test for all sand is shown on figure 4.1.

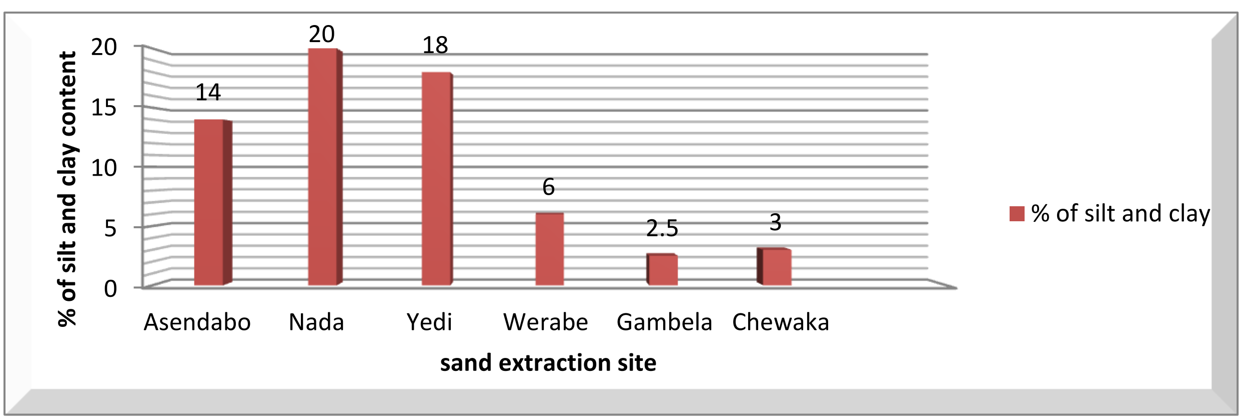

Figure 4. 1 silt and clay content of sands extracted from different site.

According to the Ethiopian Standard it is recommended to wash the sand or reject if the Silt and Clay content exceeds a value of 6%. But as we can see from the above figure 4.1, the silt and clay content of Asendabo, Yedi and Nada kela sand was above the limit specified on Ethiopian standard. Therefore a remedial measure should be taken to reduce the effect of this excess silt and clay content of sand on concrete property and to use these sands for a construction works.

4.2. Grading

The grading results showed that the Gambella , Worabe and Nada kela sand samples was much coarser sand that is why lager retaining on sieve size 4.75mm and 2.36mm which mean that these samples need blending with finer sand sample types. On other hand the Asendabo sand sample was much finer sand sample that is why larger retaining on sieve size 0.3 mm and 0.15mm this indicates that the sample needs blending with coarser sand sample types.But chewaka sand and Yedi sand has normal gradation curve which is in between the upper and the lower limit specified on ASTM and BS. The result of sieve analysis and gradation curve for all sand is shown on the appendix, annex-2.

4.2.1. Fineness modulus (FM)

The fineness modulus of the sand sample showed that the coarseness or fineness of the sand sample based on its value, which mean that the largest value of F.M indicate coarsest of sand, intermediate value of F.M shows that moderate sand sample whereas smallest value of F.M indicate finest of sand sample as shown Table 2.2 of the previous chapter. Based on this; the Worabe sand sample have the first largest value F.M which is 3.44 then Nada kela sand have the next largest Finnes modulus of 3.39 and Asendabo sand sample have the smallest value of F.M that is 1.566 .

According to ACI Committee E-701, the F.M generally ranges from 2.0 to 3.3 while ES standard ranges F.M values from 2.0-3.5 with tolerance of ± 0.2. In addition to this;. However, both the Worabe omo nada and Asendabo sand samples are not satisfying the ASTM standard requirement.

Therefore, the result of F.M showed that Worabe Sand sample was the most Coarser fine aggregate and the Asendabo sand sample was the finest fine aggregate sample. A summary of the fineness modulus (FM) for each sand samples found in Table3.3 of previous chapter.

4.3. Relationship between Silt and Clay content and Workability of the Concrete Mix.

A concrete mix, either produce on ready mix plant or on site, must be made of the right amount of cement, aggregate sand and water to make the concrete workable enough for easy compaction, placing and sufficient hardened dense concrete . If the mix is too dry, then its compaction will be too difficult and if it is too wet, then the concrete is likely to be weak.

The workability of concrete depends on the property of the ingredients. So for this research case, the slump test have been checked according to ASTM C 143 as shown in Table 4.1 and Figure 4.2 which shows the workability of the concrete mix and its change due to the gradual increment of Silt and Clay content of the sand samples from 0.94% to 18 % of the amount of the mix sand.as we can see from the following table and figure, when the silt and clay content of the sand increase from 0.94% to 18%, the slump of the concrete decreases by 73%.

Table 4. 1 shows the relationship between silt and clay content and workability of concrete.

silt and clay in %	0.94	6	10	14	18
slump in cm	37	26	17	13	10

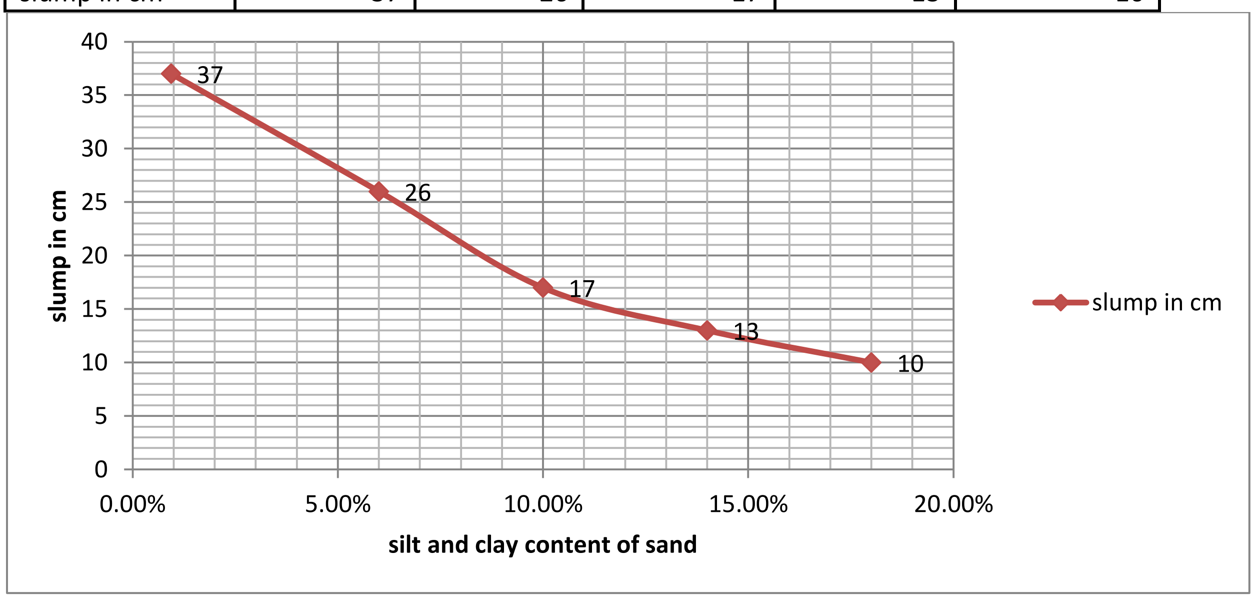

Figure 4. 2 relationship between silt and clay and workability (slump) of Concrete.

As we can see from the above figure as the silt and clay content increase from 0.94% to 18%, the slump of the concrete decreased by 73% . This show that the more silt and clay in the mix, the more the concrete become stiff and the lower the workability of the concrete. the result of this research showed the reduction in slump is due to the absorption of the mixing water which conforms with the study conducted by (Jose F, 2013) stated that the reduction in the slump of the concrete is due to the absorption of concrete mixing water by the silt and clay.

4.4. Effect of Silt and Clay content of fine aggregate on the compressive strength of concrete.

The relationship between Silt and Clay content of a natural river fine aggregate and the corresponding strength of concrete made with this aggregates are shown in Table 4.2 and Figure 4.3. From the figure a trend is apparent, where by high Silt and Clay content of aggregates produce low strength concrete.

According Ethiopian standard It is known that the maximum percentage limit of silt and clay is 6% however in this research it was observed that at this limit there was reduction in strength when we compare with the control sample having 0.94% silt and clay. But the strength reduction was not that much significant .Above this percentage limit, it was observed that the compressive strength decrease as silt and clay content increase similar to Olanitori (2006) observation. In this research work, the target strength of a C-25 concrete mix design was 33.5 MPa. However, due to some factor the test result show that the maximum compressive strength obtained for control sample was 28.88 mpa as shown on table 4.2.

Table 4. 2 summary of the relation between silt and clay content and compressive strength of concrete.

Silt and clay content %	curing Age	weight (gm)	volume of cube(cm3)	Failure load(KN)	average compressive Strength(Mpa)	Unit weight (kg/m3)
0.94	7	8270.33	3375000	406.2	18.053	2450.47
	28	8162.67	3375000	649.95	28.88	2418.57
6	7	8345.33	3375000	357.45	15.86	2472.69
	28	8237.67	3375000	541.59	25.56	2440.79
10	7	8398.33	3375000	318.95	14.18	2488.39

	28	8324	3375000	486.15	21.61	2466.37
14	7	8473	3375000	281.47	12.51	2510.52
	28	8398	3375000	402.67	17.89	2488.29
18	7	8515	3375000	240.45	10.68	2522.96
	28	8403.67	3375000	350.17	15.56	2489.97

Table 4.2 shows the average compressive strength of five samples with varying silt and clay content of sands and it was observed that the silt and clay content is inversely proportion with compressive and workability of concrete. When the silt and clay content of sand increase, the compressive strength of the concrete decrease. As it was observed from the test result the strength reduction is due to poor bondage of cement paste with aggregate and due to the effect of silt and clay on hydration reaction because when the content of silt and clay increase, the concrete mix become more stiff, it was noticed that due to high amount of fine material, the surface area increase the absorption of the mixing water. So that, the rate of hydration be affected .and also due to the absorption of the mixing water, the workability of the concrete be affected.

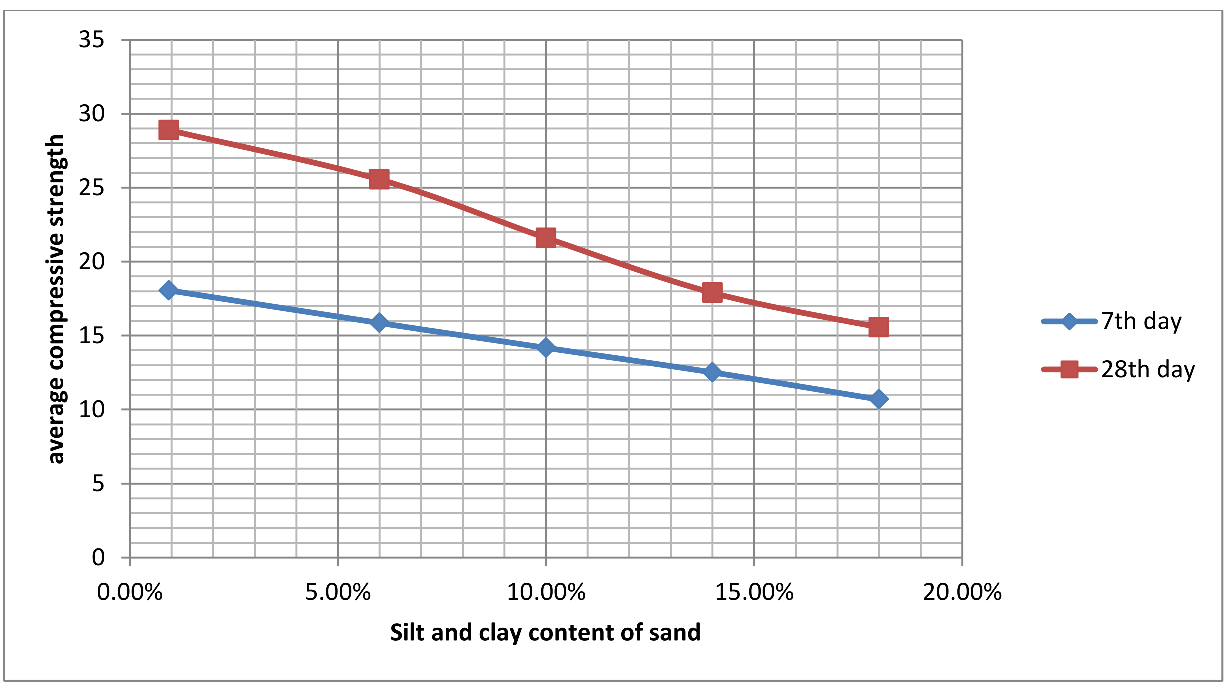

Figure 4. 3 Relationship between silt and clay content and compressive strength of concrete.

As we can see from the above figure the average compressive strength obtained from 28 curing days test result for 0.94% , 6%, 10%, 14% and 18% silt and clay content are 28.88, 25.55, 21.6, 17.89 and 15.6 mpa respectively and the percentage reduction are 11.5%, 25.22%, 38% and 46% respectively .it is noticed that when the silt and clay content increase from 0.94% to 18% the percentage strength reduction is 46% .

4.5. Relationship between cement increment and workability of concrete.

Cement paste is the binder in concrete or mortar that holds the fine aggregate, coarse aggregate, or other constituent's together in a hardened mass. A trial of cement was added to neutralize the effect of silt and clay content of sand and to maintain the compressive strength of concrete obtain ned for control sample (washed sample) which is 28.88mpa.

Table 4. 3 summary of the relation between cement increment for 6% silt and clay content of sand and compressive and workability of concrete.

cement increment	curing age(d)	weight(kg)	volume	failure load	ave. comp. strength	Density(kg/m3)	slump(cm)
3%	7 28	8302.6667 8190	3375000 3375000	390.75 572.4	17.37 25.44	2460.049 2426.667	28
5%	7 28	8358 8259.3333	3375000 3375000	421.5 652.71	18.73 29.01	2476.444 2447.21	31
10%	7 28	8429 8320.6667	3375000 3375000	450.38 677.1	20.017 30.09	2497.481 2465.383	38

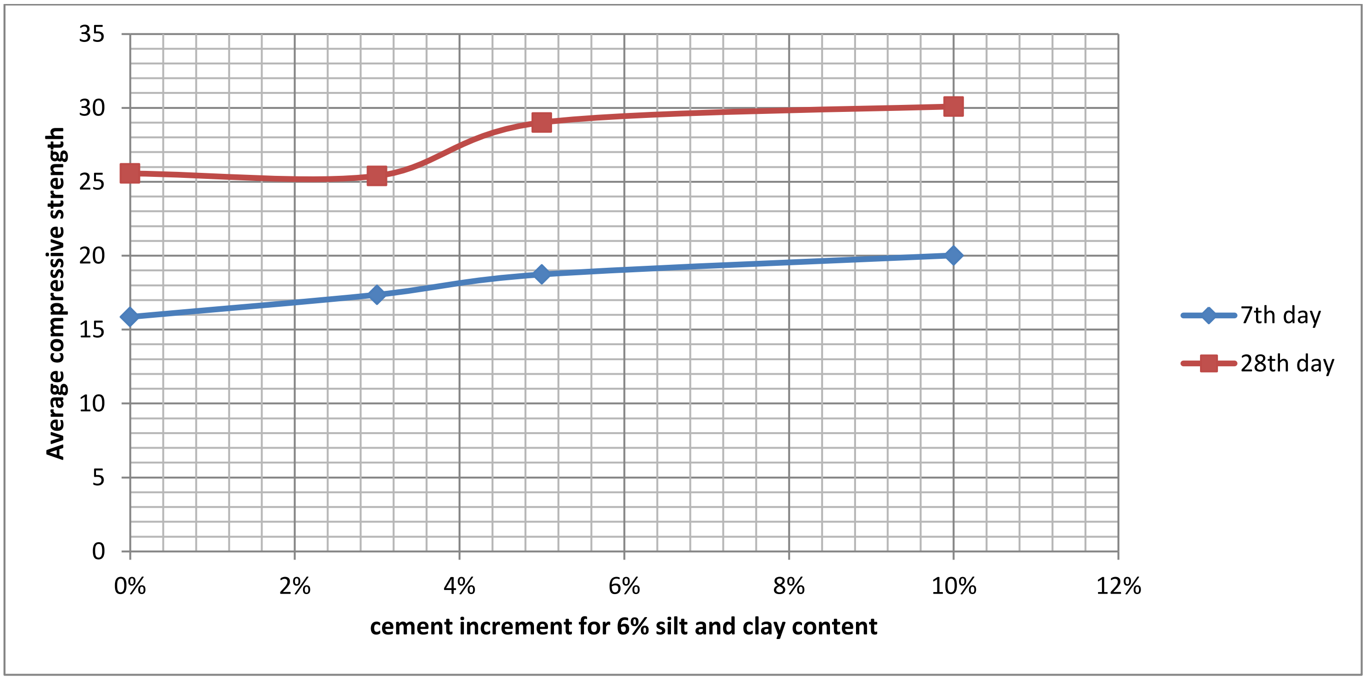

Figure 4. 4 Relationship between cement increment for 6% silt and clay content and compressive strength of concrete.

As it can be observed from fig 4.4 , 4.5% of additional cement is required to nuetrilize the effect of 6% silt and clay content of sand and to maintain the compressive strength of 28.88mpa which is obtained by using washed sand of 0.94% of silt and clay content.

Table 4. 4 summary of the relation between cement increment for 10% silt and clay and compressive strength and workability of concrete.

cement increment	curing age(d)	weight(kg)	Volume(cm3)	failure load	ave. comp. strength	density(kg/m3))	slump(cm)
5%	7	8293.7	3375000	356.78	15.86	2457.38	16
	28	8181	3375000	509.63	22.65	2424	
10%	7	8349	3375000	387.75	18.23	2473.77	28
	28	8250.3	3375000	564.53	27.09	2444.5	
15%	7	8419.3	3375000	492.23	22.877	2494.617	32
	28	8311.7	3375000	707.25	33.43	2462.72	

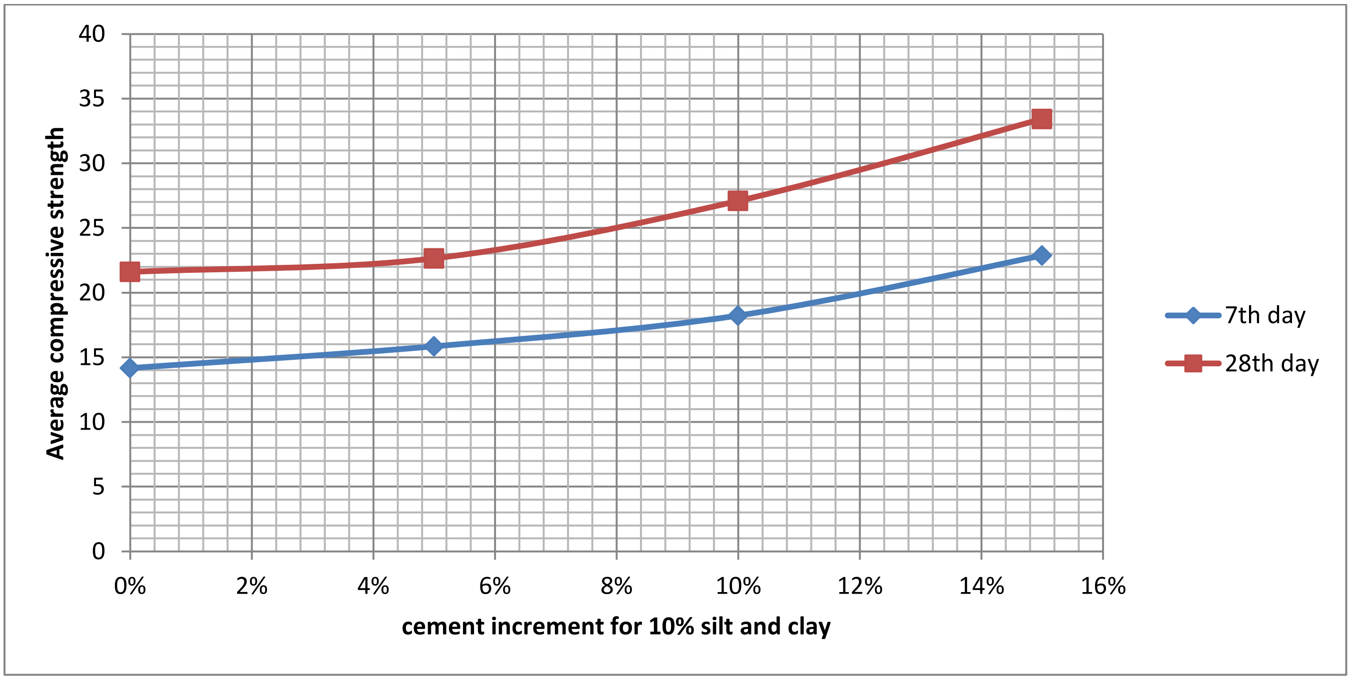

Figure 4. 5 Relation between cement increment for 10% silt and clay and compressive strength of concrete.

As it can be observed from fig 4.5 , 11% of additional cement is required to nuetrilize the effect of 10% silt and clay content of sand and to maintain the compressive strength at 28 curing days of 28.88mpa which is obtained by using washed sand of 0.94% of silt and clay content.

Table 4. 5 show the relation between cement increment for 14% silt and clay and compressive strength and workability of concrete.

cement increment	curing age	weight(kg)	volume	failure load	ave. comp. strength	Density(kg/m3)	slump(cm)
10%	7	8327.667	3375000	297.1875	13.21	2467.457	17
	28	8215	3375000	435.525	19.356	2434.074	
15%	7	8483	3375000	368.1	16.36	2513.481	27
	28	8384.333	3375000	549.6	24.42667	2484.247	
20%	7	8553.333	3375000	421.5075	18.73367	2534.321	36
	28	8445.667	3375000	631.65	28.07333	2502.42	

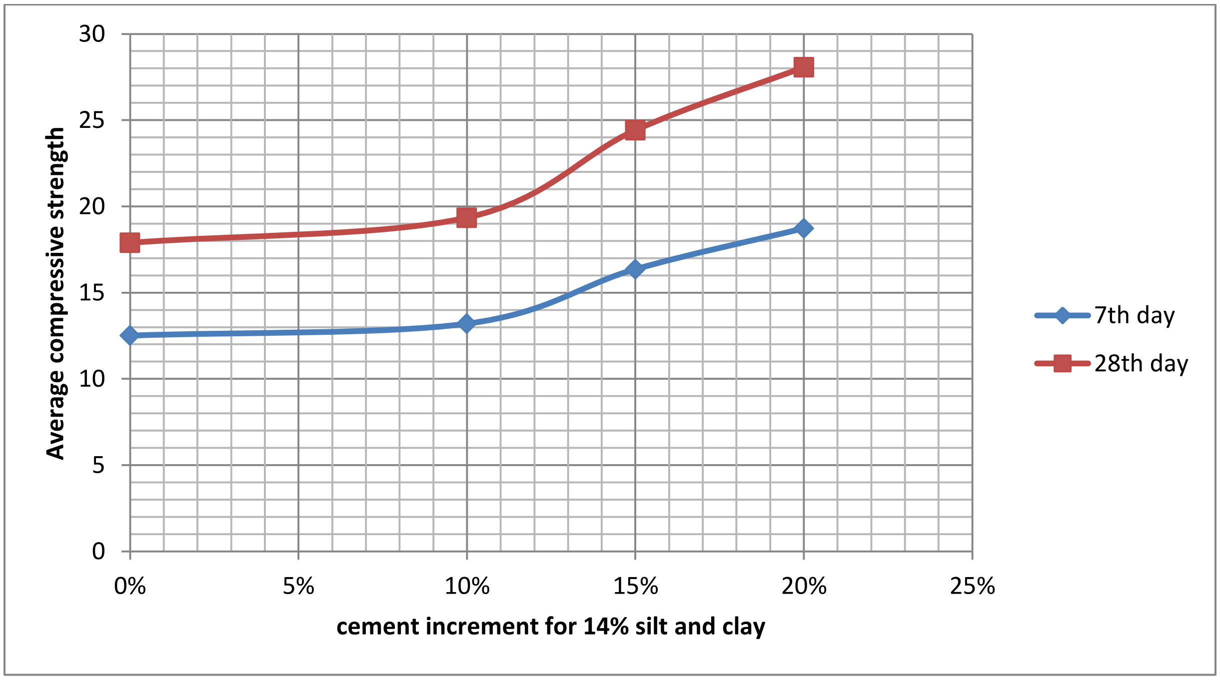

Figure 4. 6 relation between cement increment for sand having 14% silt and clay and compressive strength of concrete.

As it can be observed from fig 4.6 , 21% of additional cement is required to nuetrilize the effect of 14% silt and clay content of sand and to maintain the compressive strength at 28 curing days of 28.88mpa which is obtained by using washed sand of 0.94% of silt and clay content.

Table 4. 6 summary of the relation between cement increment for sand containing 18% silt and clay and compressive strength and workability of concrete.

cement increment	curing age(day	weight(kg)	Volume(cm3	failure load	ave. comp. strength	Density(kg/m3)	Slump(cm)
15%	7	8402.667	3375000	303.98	13.51	2489.68	22
	28	8290	3375000	444.6	19.76	2456.29	
20%	7	8508	3375000	350.93	15.59	2520.89	31
	28	8409.333	3375000	543.75	24.17	2491.65	
25%	7	8578.333	3375000	418.08	18.58	2541.73	43
	28	8520.667	3375000	612.45	27.22	2524.64	

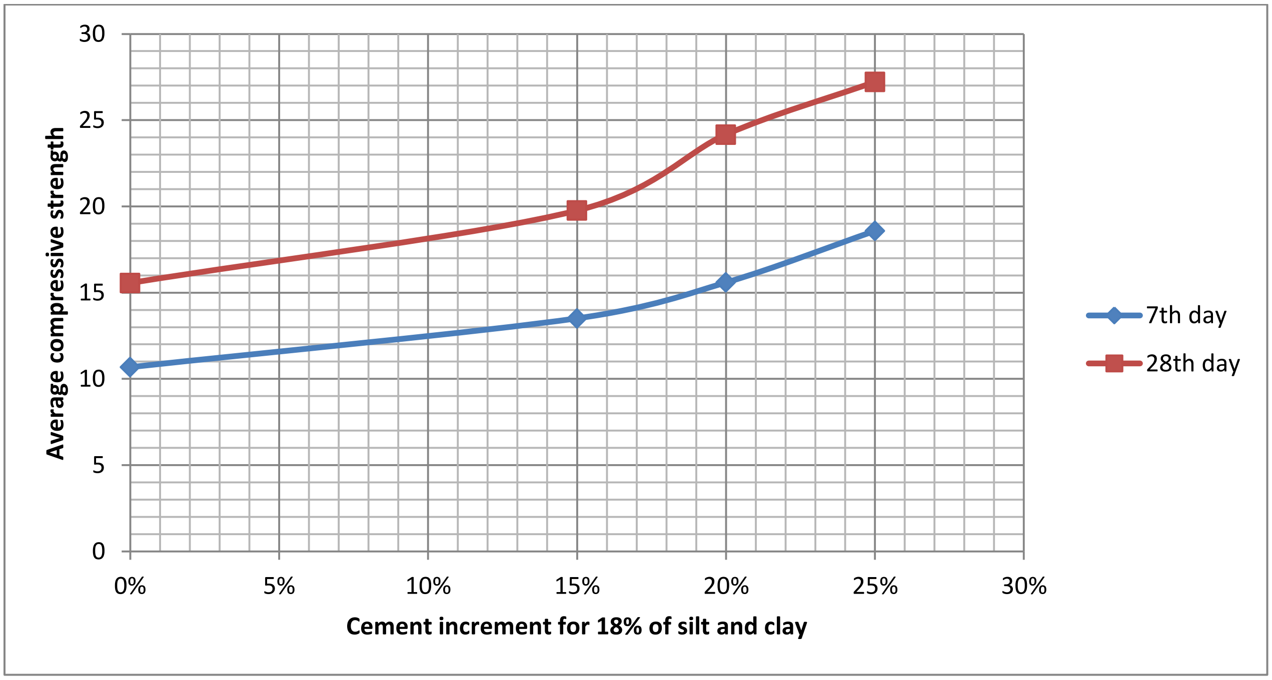

Figure 4. 7 Relation between cement increment for 18% silt and clay content of sand and compressive strength of concrete.

As it can be observed from fig 4.7 , 27% of additional cement is required to nuetrilize the effect of 18% silt and clay content of sand and to maintain the compressive strength at 28 curing days of 28.88mpa which is obtained by using washed sand of 0.94% of silt and clay content.

Table 4. 7 summary of the relation b/n silt and clay and required cement increment to maintain the compressive strength of concrete.

Silt and clay content (%)	% of cement increment	Compressive strength(mpa)
0.94 (washed)	0	28.88
6	4.5	28.88
10	11	28.88
14	21	28.88
18	27	28.88

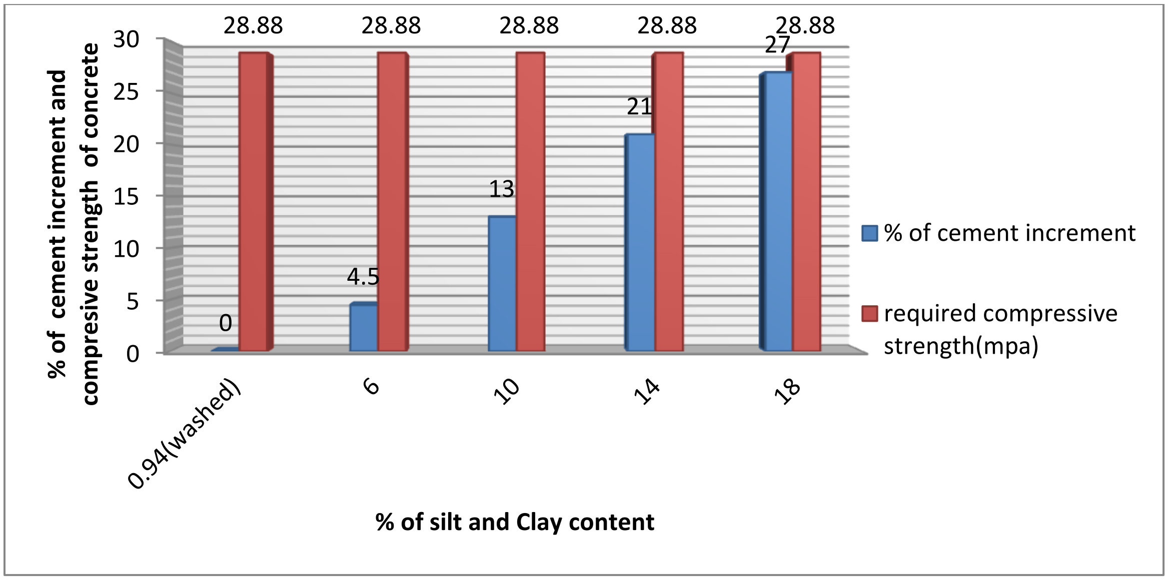

Figure 4. 8 show the relation between % of silt and clay and % of required cement increment to maintain the compressive strength of concrete.

Even though the cement content above the optimum value does not increase the strength of concrete, from the study it has been noticed that the compressive strength of the concrete is directly proportional to the amount of additional cement added in the mix. Because the Total cement content used for 1m3 concrete including the additional cement used for this research is below the maximum cement content which is 550Kg/m3 stated by EBCS 2,1995. As the strength of concrete increase, the amount of cement required also increase so that the extra cement may have an impact like shrinkage and thermal cracking. But since the largely used class of concrete used in Jimma is C-25 concrete , cement increment can be used if the silt and clay content of the sand is below 10% and if the strength of concrete used is below 25MPa.

Table 4. 8 summary of the relationship between cement increment and workability of concrete.

Silt and clay content in %	% of cement increment	slump in mm
0.94(washed)	0	37
6	4.5	30
10	11	30.5
14	21	37
18	27	44

From the test result it was observed that when cement increase, the slump of the mix also increase. As we see from the above table 4.8 , at 0% of cement increment for sand having 0.94% silt and clay , the slump was 37mm but when the cement increase by 27% for sand containing 18% silt and clay the slump of the concrete become 44mm . this indicate that cement has directly proportion with workability of concrete.

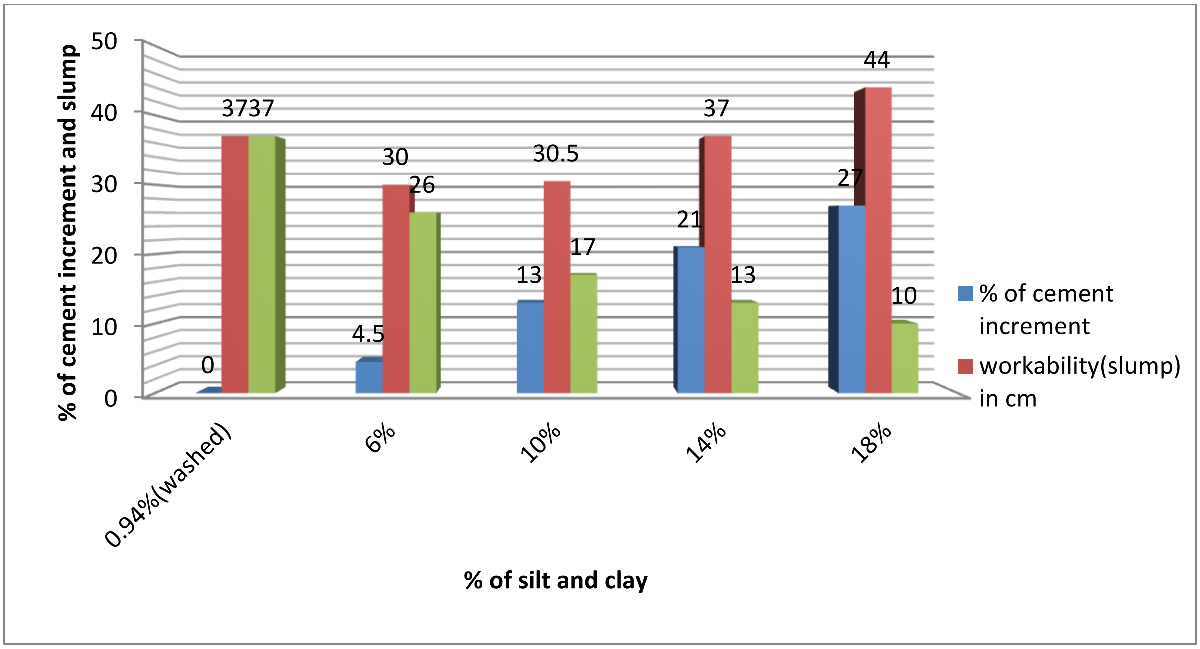

Figure 4. 9 show the relation between n cement increment and workability of concrete.

From the fig 4.9, it has been noticed that the workability of the concrete is directly proportional to the amount of additional cement added in the mix . Any increment of cement increases the slump of the concrete.

4.6. COST ANALYSIS.

The very large portion of project cost is gone to material cost. As the material cost component of construction industry cover between 55-70% of the total construction, proper consideration shall be given in the planning to design with easily available material without compromising the quality for intended purpose and for proper flow and storage of material.

4.6.1. Cost of washing the sand.

In washing the sand, the time and the amount of water needed to wash specific volume of sand was determined so that the time taken to wash 20 kg of sand having silt and clay of 18% was recorded as 34 min and the amount of water required to wash this sand until the level of silt and clay reduced to 0.94% was 80 litter. From mix design 731.4kg of sand was needed to produce 1m3 concrete.

a) Labor cost

Time required to wash 20kg of sand containing 18% silt/clay is 34 min

Time of labor work per day is 8hour or 480 min

Wage of labor per day =80 ETB, wage of labor per min=80/480=0.16667ETB

Wage of labor to wash 20kg of sand=34*0.16667=5.666ETB

Wage of labor to wash 731.4kg sand=(731.4/20)*5.666=**207.23ETB**

b) Water cost

Amount of water required to wash 20 kg of sand having 18% silt/clay =80 litter

Amount of water required to wash 731.4kg of sand=(731.4/20)*80=2925.6 litter

Price of water per 1 liter =0.0038ETB

Cost of water required to wash 731.4kg of sand=2925.6*0.0038=11.112ETB

Total cost of washing =207.23ETB+11.112ETB= **218.35ETB**

The result of the washing cost for all percent of silt/clay is tabulated as follow.

TAble 4. 9 shows washing cost for all percent of silt and clay.

silt/clay content(%)	sand per m3 (kg)	time required(min)	labor cost(ETB)	amount of water(L)	cost of water(ETB	total washing cost (ETB)
0.94	731.4	0	0	0	0	0
6	731.4	511.1535	85.19395685	1202.71416	4.57031380	89.764270
10	731.4	731.4	121.853677	1720.2528	6.53696064	128.39063
14	731.4	1023.92	170.6573181	2409.2316	9.15508008	179.81239
18	731.4	1243.38	207.2341446	2925.6	11.11728	218.35142

4.6.2. Cost of cement increment.

Although Cement content above the optimum value may not increase the strength of concrete, sufficient volume of cement paste is needed to over fill the void in the compacted aggregate and to form dense concrete. And also increasing cement will result in higher workability of the mix. In this research extra cement was added with proportion to silt and clay to neutralize the effect of this silt and clay or to maintain the binding property of the cement and to increase the rate of hydration. From mix design 360kg of cement is needed to produce 1m3 concrete having 25 mpa Even though the test for concrete compressive strength was conducted by OPC cement, the cost of cement increment is done by using the price of OPC and PPC cement because the largely used cement in Jimma town is PPC cement . The additional cement required for mitigation of the effect of silt and clay for 1 m3 of concrete was calculated as follow.

For OPC cement

Amount of cement per 1m3=360kg , taken from mix design

Price of 50kg(1bag) cement=200ETB (including VAT)

Price of 1kg cement=200/50=4ETB

For sand containing 6% silt and clay, 4.5% of cement is added to maintain the compressive strength of 28.88Mpa. therefore 4.5% *360kg=16.2kg of cement is required in 1m3 concrete.

Cost of 16.2kg cement =16.2*4=64.8ETB

The result of the other percentage of silt and clay content is tabulated as follow

TAble 4. 10 shows cost for additional opc cement used for mitigation

Silt and clay content(%)	% of cement increment	additional cement/1m3(kg)	cement cost(birr)
0.94(washed)	0	0	0
6	4.5	16.2	64.8
10	11	39.6	158.4
14	21	75.6	302.4
18	27	97.2	388.8

For PPC Cement

Price of 50kg(1bag) cement=150ETB (including VAT)

Price of 1kg cement=150/50=3ETB

TAble 4. 11 shows cost for aditional ppc cement used for mitigation

Silt and clay content(%)	% of cement increment	additional cement/1m3(kg)	cement cost(birr)
0.94(washed)	0	0	0
6	4.5	16.2	48.6
10	11	39.6	118.8
14	21	75.6	226.8
18	27	97.2	291.6

4.6.3. Material cost of 1m3 concrete for different sand

TAble 4. 12 Market value of sand in Jimma Town

extruction site	Yedi	Asendabo	Nada	Ganbela	Werabe	Chewaka
in 16m3 dumtruck	8000	7000	7000	16000	14000	14000
in m3	500	437.5	437.5	1000	875	875

TAble 4. 13 Material cost of 1m3 concrete by using different sand

sand type	Yedi	Asendabo	Nada	Ganbela	Werabe	Chewaka
Using OpC	2256	2223	2223	2512	2448	2448
Using PPC	1896	1864	1864	2152	2088	2088

TAble 4. 14 Additional cost due to washing and due to cement increment in percent when opc cement is used.

silt and clay	washing cost	cost additional cement	cost of 1m3 concrete	% cost increment due to washing	% cost increment due to additional cement
0.94	0	0	2256.053755	0	0
6	89.764271	64.8	2256.053755	3.97882	2.87227199
10	128.39064	158.4	2256.053755	5.69094	7.0211093
14	179.8124	302.4	2256.053755	7.97022	13.4039359
18	218.35142	388.8	2256.053755	9.67847	17.2336319

as we can see from the above table for sand containing 6% of silt and clay , 3.98% and 2.87% of mitigation cost is required if washing and cement increment is used respectively . And for 10% of silt and clay , 5.7% of additional cost is required if washing method is used and 7% additional cost is required if OPC cement increment method of mitigation is used. And for 18% silt and clay content, 9.6% and 17.23% of additional cost is required if washing and cement increment method is used respectively. Therefore it can concluded that for sand containing more than 6% of silt and clay, it is more economical to use washing method but if and only if opc cement is used.

TAble 4. 15 Additional cost due to washing and due to cement increment in percent using ppc cement.

silt and clay in %	washing cost	cost of additional cement	cost of 1m3 concrete	% cost increment due to washing	% cost increment due to additional cement
0.94	0	0	1896.053755	0	0
6	89.764271	48.6	1896.053755	4.73427	2.56321847
10	128.39064	118.8	1896.053755	6.77147	6.26564514
14	179.8124	226.8	1896.053755	9.48351	11.9616862
18	218.35142	291.8	1896.053755	11.5161	15.389859

Table 4.15 showed the percent increment of cost due to washing and cement increment for mitigation For sand containing 10 % of silt and clay, 6.77% and 6.26% of additional cost is required if washing and cement increment is used respectively and for sand containing 14% of silt and clay, 9.48% and 11.96 and for sand containing 18% , 11.51% and 15.4% of additional cost is required if washing and cement increment is used respectively. There fore it is more economical to use cement increment if silt and clay content is less than 10% and washing method if silt and clay content is more than 10%.

CHAPTER FIVE

5. CONCLUSION AND RECOMENDATION

5.1. Conclusion

From the study it is observed that

1. The building sand being supplied to Jimma town contained silt and clay content that exceeded the allowable limit specified on Ethiopian standard. The level of silt and clay content range from 2.5% to 20%.
2. The compressive strength and the workability of the concrete are indirectly proportional to the amount of silt and clay in the fine aggregate. Any increment of this finer material decreases the strength and workability of the concrete. As the silt and clay content increase from 0.94% to 18%, the percentage reduction of the compressive strength is 46.12%.
3. Additional cement is required to neutralize the effect of silt and clay content of sand and to maintain the compressive strength of 28.88mpa which is obtained by using washed sand having 0.94% of silt and clay. Blending of 30**%** Asendabo sand with 70% Gambela sand and 20% yedi sand with 80% Chewaka sand reduce the level of silt and clay to 6% and also 40% of Asendabo sand with 60% Werabe sand combining with another mitigation measure can be used for producing quality and cost effective concrete.

4. The process of mitigation increases the cost of production of 1m3 of concrete by 4.73%-11.5% if washing method is used and between 2.5% - 15.4% if cement increment method is used, depending on the silt and clay content of sand. For sand containing less than 10% silt and clay content, it is more economical to use the cement increment method of mitigation, while on the other hand, for sand containing more than 10 % silt and clay content, it is more economical to use the washing method of mitigation.

5.2. Recommendation

Based on the conclusion above, the following recommendations are made:

- ✓ In order to minimize the negative impact that Silt and Clay content have on concrete, it would be best to control the Silt and Clay content of the aggregate.
- ✓ Field Settlement Test should be carried out on any sand to be used around Jimma to ascertain the percentage of silt and clay content of the sand.
- ✓ .If the percentage of silt and clay content of the sand is more than 6%, and then remedial measures such as washing or cement increment or blending should be taken so as to mitigate the effect of silt and clay content of the sand.
- ✓ Research should be carried out on the possibility of producing a machine capable of washing sand locally.
- ✓ In order to have a safe building industry, the percentage increment should be taken into consideration by all the stake holders in the industry, especially the consultant structural engineer, consultant quantity surveyor and the client.
- ✓ Blending coarser sand with finer sand and high silt and clay content sand with low silt and clay content like blending either Gambella sand with Asendabo sand or Worabe sand with Asendabo sand in order to improve the quality of the sand that used for concrete production was recommended.

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APPENDIX:

Annex 1: Mix Design Procedures and Calculations

The mix design for C-25 non air entrained normal strength concrete is done as per ACI

The data from test results, which are important for mix design, are:

- **Properties of coarse aggregate**
  - Maximum size=25mm
  - Unit weight=1592 kg/m3
  - Specific gravity=2.65
  - Absorption=0.745%
  - Free moisture content=0.2%
  - Loose unit weight (Kg/m3)=1486kg/m3

- **Properties of fine aggregate**

- Unit weight=1560 kg/m3
- Fineness modulus=2.85
- Specific gravity=2.55
- Absorption=2.02%
- Free moisture content =1.1%
- Loose unit weight (Kg/m3) 1422
- **Specific gr. Of Cement (O.P.C) = 3.15**

Steps for mix design

Step 1: Slump

30mm -50mm (minimum slump possible) is selected.

Step 2: Maximum size of aggregate

Maximum size is fixed to be 25mm.

Step 3: Target mean strength calculation

When limited or no test data is available, the upper value which is 8.5MPa shall be added to get mean strength.

Fm = 25+8.5=33.5MPa

Step 4: W/C ratio

From ACI Table For 30MPa W/C ratio is 0.55 and for 35MPa W/C ratio is 0.48. The W/C ratio for 33.5mpa can be calculated by interpolation as follows:

$$\frac{0.55-0.48}{30-35}(33.5-30)+0.55=\mathbf{0.5}$$

Water cement ratio for special exposure from ACI

Step 5: Mixing water amount (ACI 211.1-81, table 3-11)

For maximum size of aggregate of 25mm, slump 30 to 50mm (minimum range) and non-air entrained concrete the mixing water requirement according to ACI table below

Mixing water amount = 180 Kg/M3

Entrapped air=1.5%

Step 6: Cement Amount

Cement content = 180/0.50 = 360 kg/m3

Step 7: Course aggregate amount

For maximum size aggregate=25mm and sand fineness modulus of 2.85 the dry bulk volume max. Size of 25mm can be interpolated between fineness modulus of 2.8 and 3 that is 0.665

Coarse aggregate amount = 0.665*1592=1058.7 kg/m3

But 1592kg/m3 is air dry bulk unit weight and it has to be adjusted to air dry condition and back to SSD by dividing by total moisture and multiplying by Absorption respectively. i.e. (1058.7/1.002)*1.00745 = **1064.5kg/m3**.

Step 8 fine aggregate amounts

First estimate of concrete from ACI 211.1-81

for maximum size of aggregate and non-air entrained is 2375 kg/m3

but the more exact value of total concrete unit weight can be calculated by the following formula

Um=10Ga(100-A)+[Cm(1-Ga/Gc)]-Wm(Ga-1)[kg/m3]

Um=100*2.63(100-1.5)+[360(1-2.6/3.15)]-180(2.6-1)= 2335.8 Kg/m3

Fine aggregate=2335.8-360-180-1064.5=**731.4kg**

Adjustment for moisture in aggregate

Since the aggregate will be neither SSD nor OD in the field it is necessary to adjust the aggregate weight for the amount of water contained in the aggregate because the absorbed water does not become a part of the mixing water , only surface water need to be considered .

Table 1.1 adjusted mix proportion

	cement	sand	Aggregate	water	Total
constituent(Kg/m3)	360	731.4	1064.5	180	2335.9
adjustment due to Absorption		(2.02-1.1) 0.92	(0.745-0.2) 0.545		
W(stock)		738.12888	1070.301525		
Extra water		-6.72888	-5.801525	-12.5304	
Adjusted/m3	360	731.4	1064.5	192.5304	2348.43
Adjusted/cube(0.003375m3)	1.215	2.468475	3.5926875	0.64979	7.925953
Adjusted/ 6 cube(0.02025m3)	7.29	14.81085	21.556125	3.898741	47.55572

ANNEX -2 Sieve analysis and gradation curve.

Table 2.1 Sieve analysis for Yedi sand

sieve size	trial 1	trial2	trial3	average mass retained	% retained	cum % retained	cum % pass	Spec
9.5	0	0	0	0	0	0	100	100
4.75	0.01	0.013	0.014	0.012333333	0.613497	0.613497	99.3865	95-100
2.36	0.21	0.209	0.216	0.211666667	10.52893	11.14243	88.85757	80-100
1.18	0.32	0.31	0.315	0.315	15.66904	26.81147	73.18853	50-85
0.6	0.741	0.722	0.731	0.731333333	36.37871	63.19018	36.80982	25-60
0.3	0.46	0.47	0.45	0.46	22.88178	86.07196	13.92804	10—30
0.15	0.21	0.24	0.225	0.225	11.19217	97.26414	2.735865	2—10
pan	0.055	0.056	0.054	0.055	2.735865	0	0	
Total				2.010333333		285.0937		

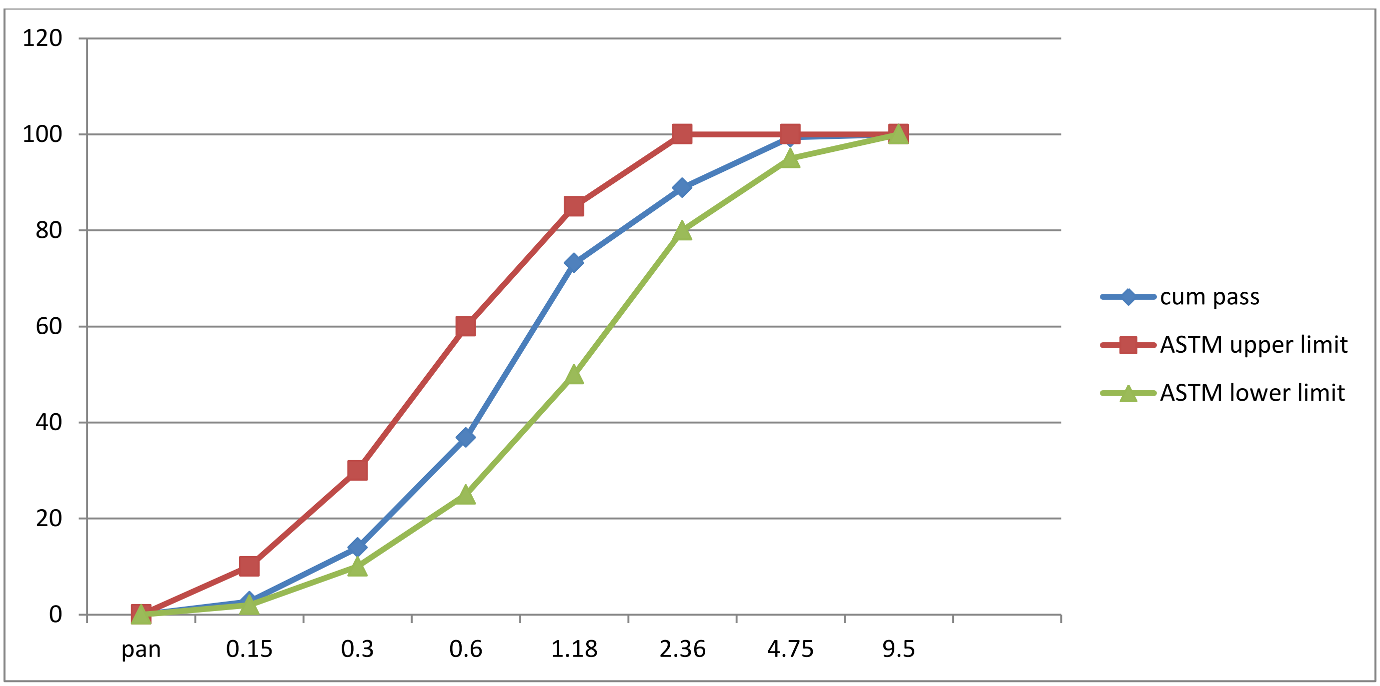

Figure 2. 10 gradation curve for Yedi sand

Table 2.2 Sieve analysis for Asendabo sand

sieve size	trial 1	trial2	trial3	average mass retained	% retained	cum % retained	cum % pass	Spec
9.5	0	0	0	0	0	0	100	100
4.75	0	0.015	0	0.005	0.249335	0.249335	99.75066	95-100
2.36	0.015	0.0175	0.0166	0.016366667	0.816157	1.065492	98.93451	80-100
1.18	0.025	0.026	0.0249	0.0253	1.261636	2.327128	97.67287	50-85
0.6	0.25	0.265	0.257	0.257333333	12.83245	15.15957	84.84043	25-60
0.3	0.475	0.485	0.462	0.474	23.63697	38.79654	61.20346	10—30
0.15	1.215	1.21	1.197	1.207333333	60.20612	99.00266	0.99734	2—10
pan	0.021	0.019	0.02	0.02	0.99734	0	0	
				2.005333333		156.6007		

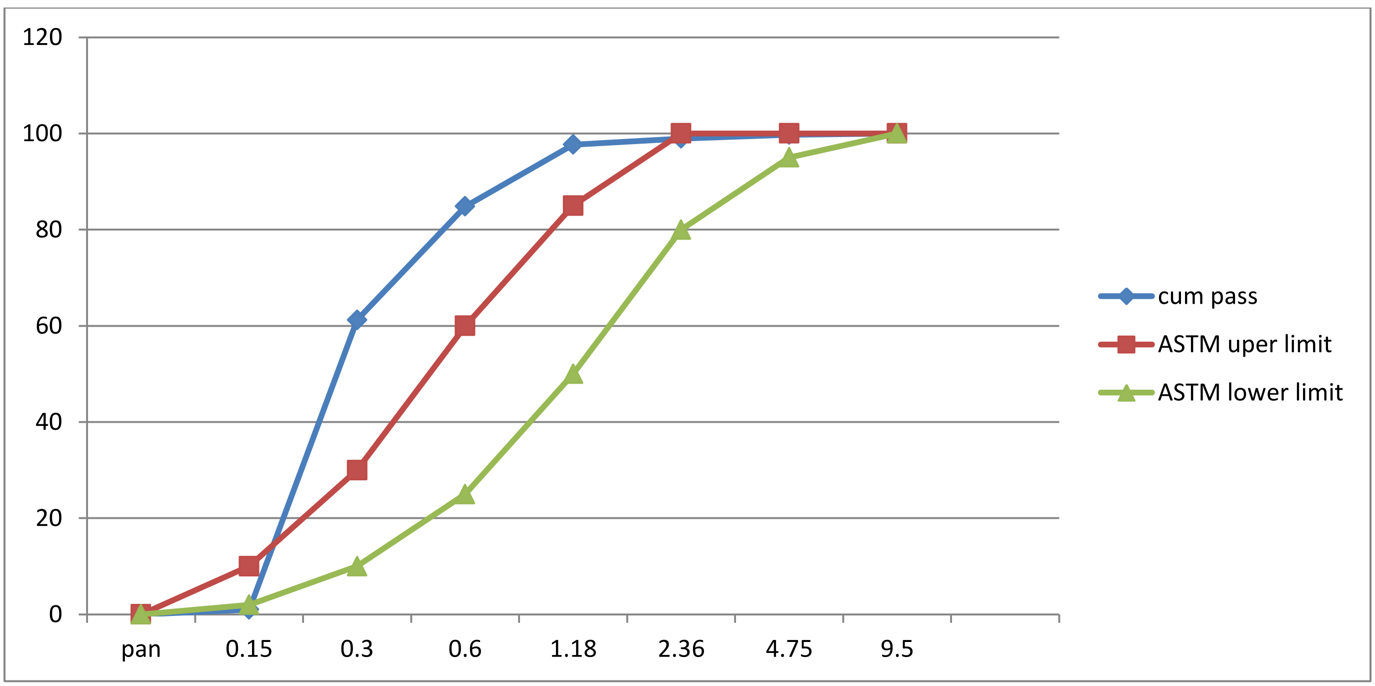

Figure 2. 11 Gradation Curve for Assendabo sand

Table 2.3 Sieve analysis for Nada Kela sand

sieve size	trial 1	trial2	trial3	average mass retained	% retained	cum % retained	cum % pass	Spec
9.5	0.014	0.07	0.02	0.034666667	0	0	100	100
4.75	0.15	0.17	0.19	0.17	8.474576	8.474576	91.52542	95-100
2.36	0.305	0.225	0.28	0.27	13.45962	21.9342	78.0658	80-100
1.18	0.5	0.475	0.49	0.488333333	24.34364	46.27783	53.72217	50-85
0.6	0.58	0.61	0.585	0.591666667	29.49485	75.77268	24.22732	25-60
0.3	0.265	0.27	0.28	0.271666667	13.54271	89.31539	10.68461	10—30
0.15	0.185	0.163	0.158	0.168666667	8.408109	97.7235	2.276504	2—10
pan	0.01	0.011	0.012	0.011	0.548355	0	0	
Total				2.006		339.4982		

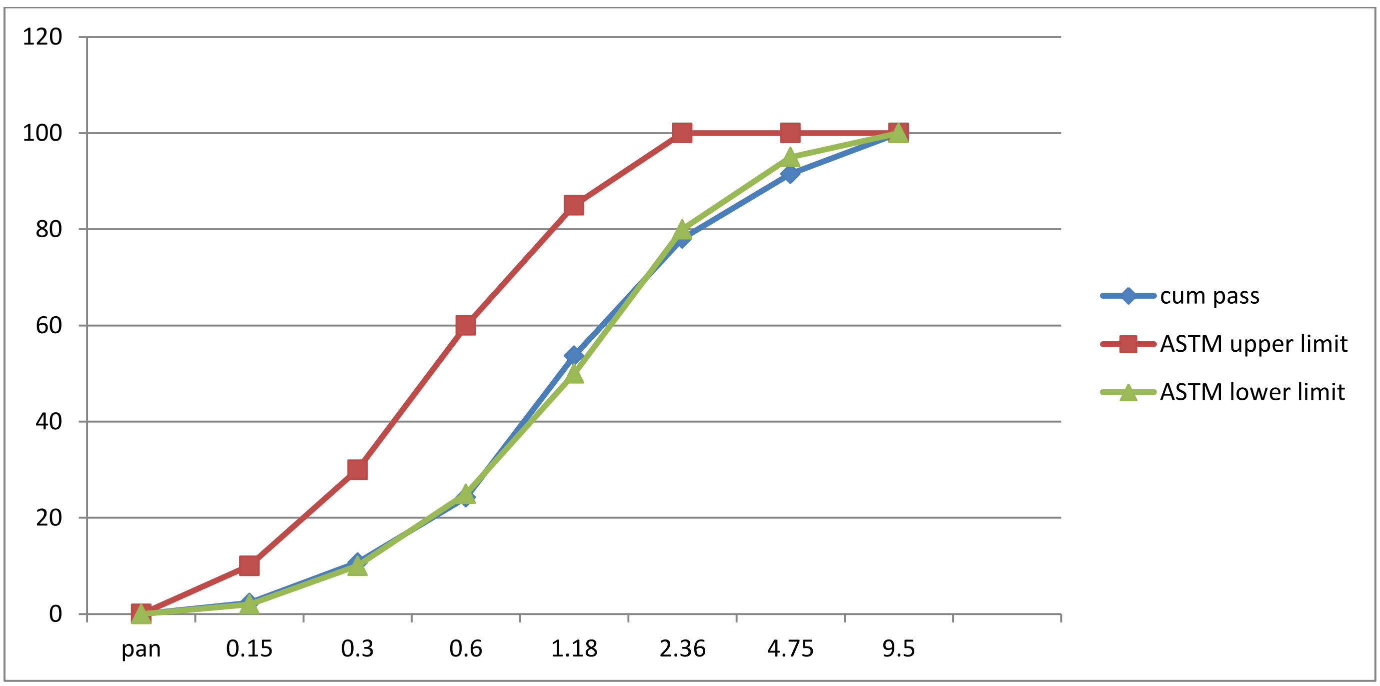

Figure 2. 12 Gradation curve for Nada kela sand

Table 2.4 Sieve analysis for Werabe sand

sieve size	trial 1	trial2	trial3	average mass retained	% retained	cum % retained	cum % pass	Spec
9.5	0.01	0.014	0.017	0.013667	0	0	100	100
4.75	0.22	0.21	0.2	0.21	10.47904	10.47904	89.52096	95-100
2.36	0.25	0.26	0.24	0.25	12.47505	22.95409	77.04591	80-100
1.18	0.31	0.29	0.32	0.306667	15.30273	38.25682	61.74318	50-85
0.6	0.72	0.752	0.731	0.734333	36.64338	74.9002	25.0998	25-60
0.3	0.295	0.27	0.27	0.278333	13.88889	88.78909	11.21091	10—30
0.15	0.198	0.18	0.21	0.196	9.780439	98.56953	1.430472	2—10
pan	0.013	0.015	0.017	0.015	0.748503	0	0	
Total				2.004		333.9488		

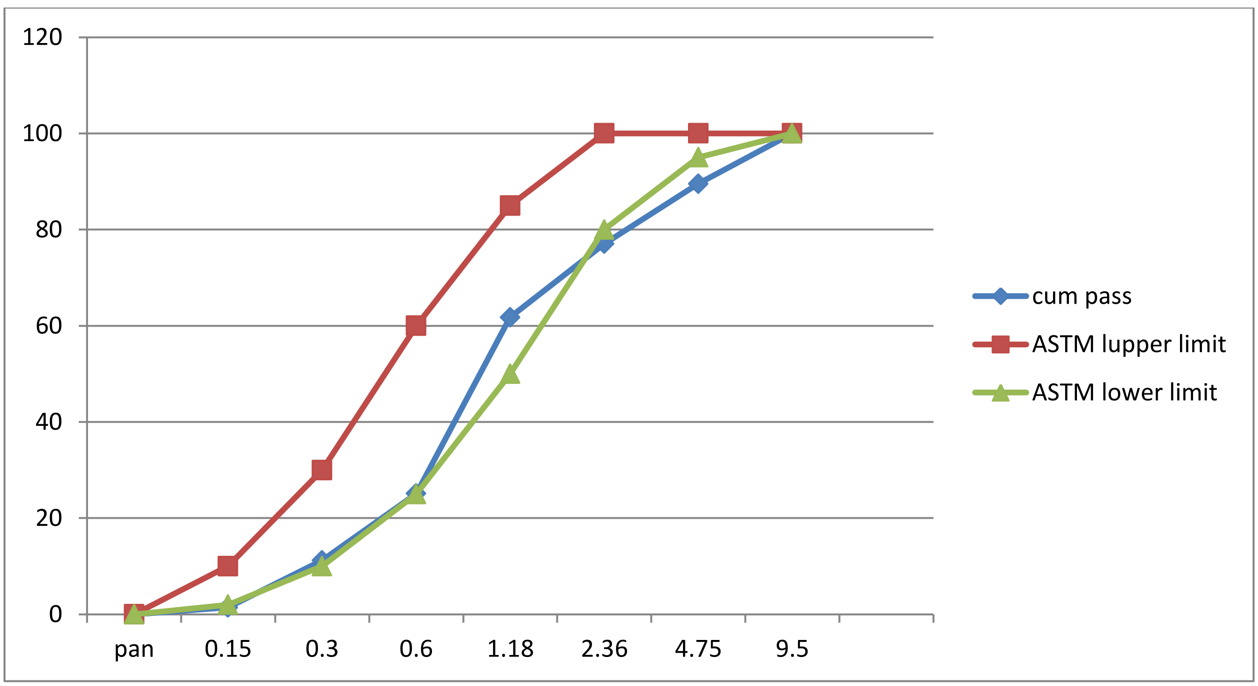

Figure 2. 13 Gradation curve for Werabe sand

Table 2.5 Sieve analysis for Gambela sand

sieve size	trial 1	trial2	trial3	average mass retained	% retained	cum % retained	cum % pass	Spec
9.5	0	0	0	0	0	0	100	100
4.75	0.019	0.015	0.015	0.016333	0.818167	0.818167	99.18183	95-100
2.36	0.255	0.258	0.245	0.252667	12.65654	13.4747	86.5253	80-100
1.18	0.4	0.41	0.39	0.4	20.03673	33.51144	66.48856	50-85
0.6	0.71	0.69	0.725	0.708333	35.48172	68.99315	31.00685	25-60
0.3	0.29	0.295	0.295	0.293333	14.6936	83.68676	16.31324	10—30
0.15	0.27	0.277	0.265	0.270667	13.55819	97.24495	2.755051	2—10
pan	0.05	0.06	0.055	0.055	2.755051	0	0	
Total				1.996333		297.7292		

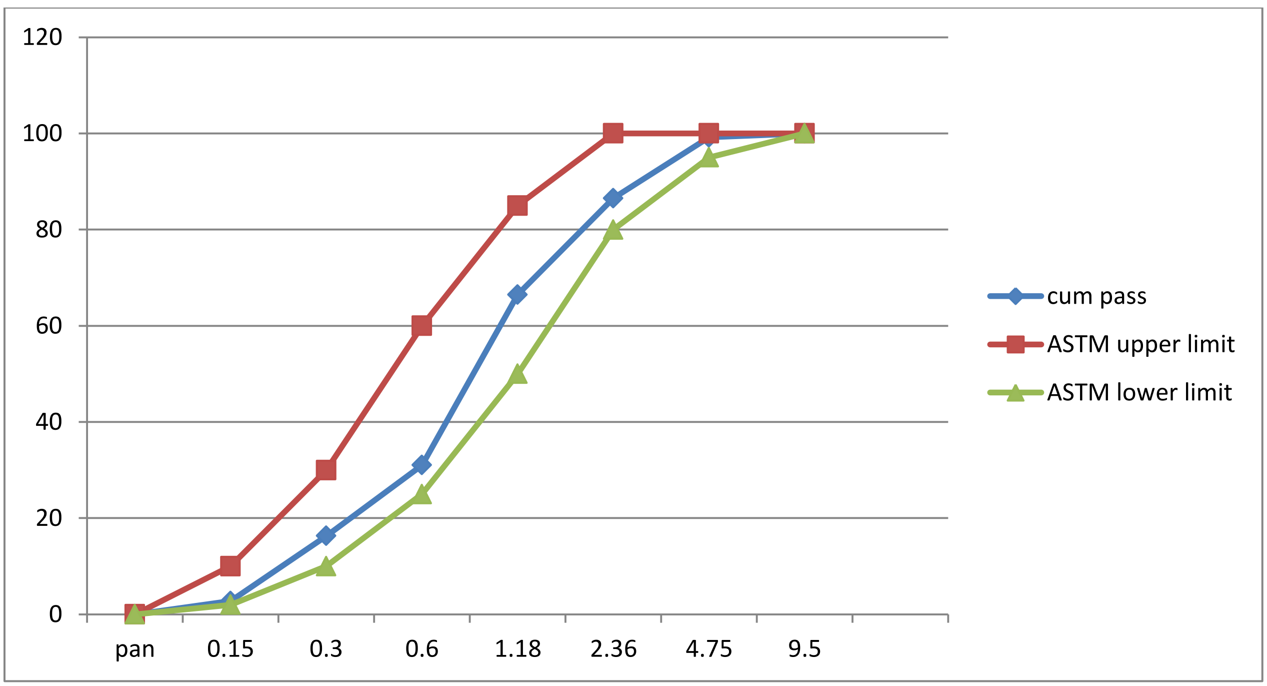

Figure 2. 14 Gradation curve for Gambela sand

Table 2.6 for CHewaka

sieve size	trial 1	trial2	trial3	average mass retained	% retained	cum % retained	cum % pass	Spec
9.5	0	0	0	0	0	0	100	100
4.75	0.017	0.19	0	0.069	3.443114	3.443114	96.55689	95-100
2.36	0.15	0.155	0.165	0.156667	7.817698	11.26081	88.73919	80-100
1.18	0.45	0.455	0.435	0.446667	22.28876	33.54957	66.45043	50-85
0.6	0.28	0.21	0.285	0.258333	12.89088	46.44045	53.55955	25-60
0.3	0.741	0.715	0.725	0.727	36.27745	82.7179	17.2821	10—30
0.15	0.345	0.323	0.338	0.335333	16.7332	99.4511	0.548902	2—10
pan	0.01	0.011	0.012	0.011	0.548902	0	0	
Total				2.004		276.8629		

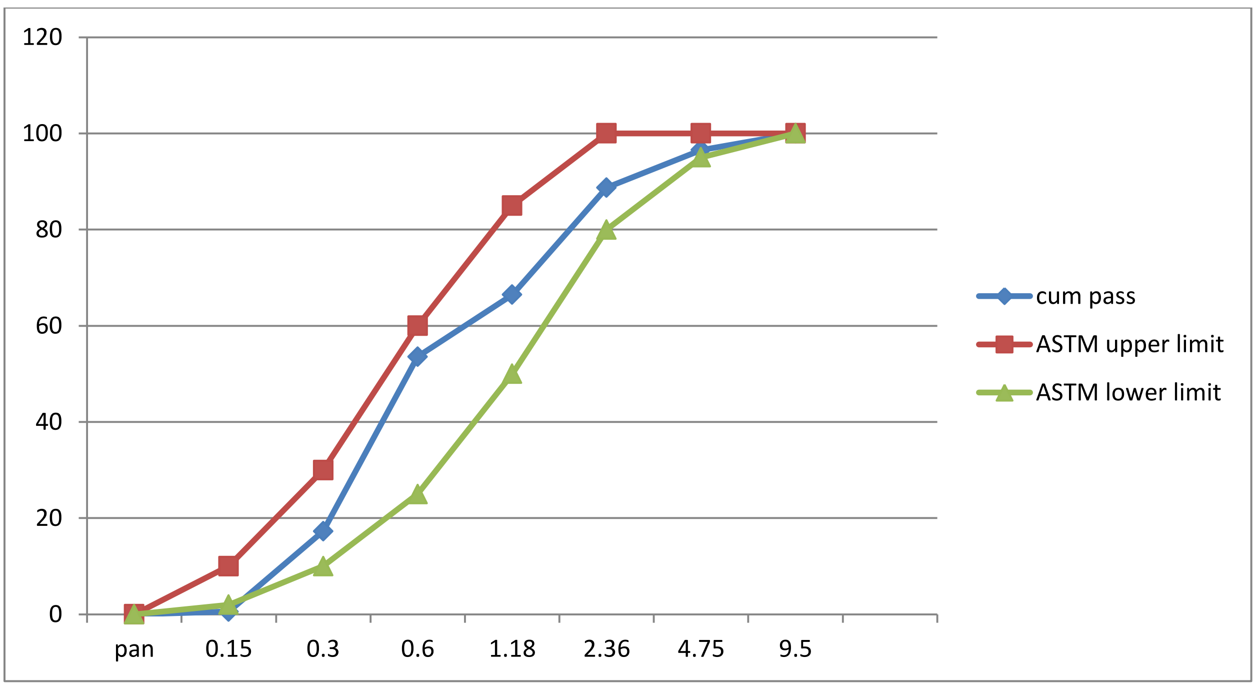

Figure 2. 15 Gradation curve for chewaka sand

ANNEX -3 laboratories test Result

Table 3.1 relation between Silt and clay content of sand and workability and compressive strength of concrete.

silt and clay content	curing Age	no of sample	weight (kg)	volume of cube(cm3)	Failure load(KN)	Compressive strength in (Mpa)	Unit weight (kg/m3)	Slump in mm
0%	7	1	8540	3375000	389.475	17.31	2530.37037	37
		2	8478	3375000	405.9	18.04	2512	
		3	8527	3375000	423.225	18.81	2526.51852	
		mean	8515	3375000	406.2	18.0533333	2522.96296	
	28	1	8498	3375000	623.475	27.71	2517.92593	
		2	8436	3375000	691.65	30.74	2499.55556	
		3	8486	3375000	634.725	28.21	2514.37037	
		mean	8473.3	3375000	649.95	28.8866667	2510.61728	
6%	7	1	8498	3375000	337.95	15.02	2517.92593	26
		2	8436	3375000	360.9	16.04	2499.55556	
		2	8485	3375000	371.475	16.51	2514.07407	
		mean	8473	3375000	356.775	15.8566667	2510.51852	
	28	1	8256	3375000	564.3	25.08	2446.22222	
		2	8594	3375000	555.75	24.7	2546.37037	
		3	8444	3375000	537.525	23.89	2501.92593	
		mean	8431.3	3375000	552.525	24.5566667	2498.17284	
10%	7	1	8425	3375000	317.7	14.12	2496.2963	17
		2	8359	3375000	311.625	13.85	2476.74074	
		2	8411	3375000	327.6	14.56	2492.14815	
		mean	8398.3	3375000	318.975	14.1766667	2488.39506	
	28	1	8282	3375000	472.725	21.01	2453.92593	
		2	8320	3375000	480.15	21.34	2465.18519	
		3	8370	3375000	505.575	22.47	2480	
		mean	8324	3375000	486.15	21.6066667	2466.37037	
14%	7	1	8372	3375000	272.25	12.1	2480.59259	13
		2	8306	3375000	311.625	13.85	2461.03704	
		3	8358	3375000	260.55	11.58	2476.44444	
		mean	8345.3	3375000	281.475	12.51	2472.69136	
	28	1	8129	3375000	384.75	17.1	2408.59259	
		2	8267	3375000	421.65	18.74	2449.48148	
		3	8317	3375000	401.625	17.85	2464.2963	

		mean	8237.7	3375000	402.675	17.8966667	2440.79012	
18%	7	1	8297	3375000	243.675	10.83	2458.37037	10
		2	8231	3375000	247.725	11.01	2438.81481	
		3	8283	3375000	229.95	10.22	2454.22222	
		mean	8270.3	3375000	240.45	10.6866667	2450.46914	
	28	1	8054	3375000	339.75	15.1	2386.37037	
		2	8192	3375000	331.65	14.74	2427.25926	
		3	8242	3375000	379.125	16.85	2442.07407	
		mean	8162.7	3375000	350.175	15.5633333	2418.5679	

`Table 3.2 Summary of the relation between silt/clay content and compressive strength and workability of concrete

silt/clay content %	curing Age	weight (gm)	volume of cube(cm3)	Failure load(KN)	average compressive strength in (Mpa)	Unit weight (kg/m3)	slump In cm
0	7	8270.333	3375000	406.2	18.05333333	2450.46914	37
	28	8162.667	3375000	649.95	28.88666667	2418.5679	
6	7	8345.33	3375000	357.45	15.856666	2472.69136	26
	28	8237.667	3375000	541.59	25.55666667	2440.79012	
10	7	8398.333	3375000	318.95	14.17666667	2488.39506	17
	28	8324	3375000	486.15	21.60666667	2466.37037	
14	7	8473	3375000	281.47	12.51	2510.51852	13
	28	8398	3375000	402.67	17.89666667	2488.2963	
18	7	8515	3375000	240.45	10.68666667	2522.96296	10
	28	8403.667	3375000	350.17	15.56333333	2489.97531	

Table 3.3 a trial of cement increment for sand having 6% silt and clay.

Cement Increment	curing Age	no of sample	weight (gm)	volume of cube(cm3)	Failure load(KN)	comp. strength (Mpa)	Unit weight (gm/cm3)
3%	7	1	8286	3375000	389.475	17.31	2455.111
		2	8265	3375000	377.55	16.78	2448.889
		3	8357	3375000	405.225	18.01	2476.148
		mean	8302.667	3375000	390.75	17.36667	2460.049
	28	1	8212	3375000	599.175	26.63	2433.185
		2	8232	3375000	539.325	23.97	2439.111
		3	8126	3375000	578.7	25.72	2407.704
		mean	8190	3375000	572.4	25.44	2426.667
5%	7	1	8410	3375000	411.975	18.31	2491.852
		2	8350	3375000	424.8	18.88	2474.074
		3	8314	3375000	427.725	19.01	2463.407
		mean	8358	3375000	421.5	18.73333	2476.444
	28	1	8221	3375000	614.7	27.32	2435.852
		2	8343	3375000	653.58	29.048	2472
		3	8214	3375000	689.85	30.66	2433.778
		mean	8259.333	3375000	652.71	29.00933	2447.21
10%	7	1	8454	3375000	434.475	19.31	2504.889
		2	8392	3375000	467.55	20.78	2486.519
		2	8441	3375000	449.1225	19.961	2501.037
		mean	8429	3375000	450.3825	20.017	2497.481
	28	1	8212	3375000	620.55	27.58	2433.185
		2	8350	3375000	730.35	32.46	2474.074
		2	8400	3375000	680.4	30.24	2488.889
		mean	8320.667	3375000	677.1	30.09333	2465.383

Table 3.4 a trial of cement increment for sand having 10% silt and clay.

Cement Increment	curing Age	no of sample	weight (gm)	volume of cube(cm3)	Failure load(KN)	comp. strength (Mpa)	Unit weight (gm/cm3)
5%	7	1	8277	3375000	362.475	16.11	2452.4444
		2	8256	3375000	325.125	14.45	2446.2222
		3	8348	3375000	382.725	17.01	2473.4814
		mean	8293.66666	3375000	356.775	15.8566666	2457.3827
	28	1	8203	3375000	517.725	23.01	2430.5185
		2	8223	3375000	464.4	20.64	2436.4444
		3	8117	3375000	546.75	24.3	2405.0370
		mean	8181	3375000	509.625	22.65	2424
10%	7	1	8401	3375000	391.725	18.41	2489.1851
		2	8341	3375000	411.3	19.28	2471.4074
		3	8305	3375000	360.225	17.01	2460.7407
		mean	8349	3375000	387.75	18.2333333	2473.7777
	28	1	8212	3375000	584.55	27.98	2433.1851
		2	8334	3375000	579.375	27.75	2469.3333
		3	8205	3375000	529.65	25.54	2431.1111
		mean	8250.33333	3375000	564.525	27.09	2444.5432
15%	7	1	8446	3375000	481.95	22.42	2502.5182
		2	8380	3375000	500.625	23.25	2482.9629
		2	8432	3375000	494.1225	22.961	2498.3703
		mean	8419.33333	3375000	492.2325	22.877	2494.6172
	28	1	8203	3375000	669.375	31.75	2430.5185
		2	8341	3375000	715.05	33.78	2471.4074
		3	8391	3375000	737.325	32.77	2486.2222
		mean	8311.66666	3375000	707.25	33.4333333	2462.7160

Table 3.5 a trial of cement increment for sand having 14% silt and clay.

Cement increment	curing Age	no of sample	weight (gm)	volume of cube(cm3)	Failure load(KN)	comp. strength (Mpa)	Unit weight (gm/cm3)
10%	7	1	8311	3375000	302.9625	13.465	2462.519
		2	8290	3375000	318.375	14.15	2456.296
		3	8382	3375000	270.225	12.01	2483.556
		mean	8327.667	3375000	297.1875	13.20833	2467.457
	28	1	8237	3375000	465.975	20.71	2440.593
		2	8257	3375000	454.725	20.21	2446.519
		3	8151	3375000	385.875	17.15	2415.111
		mean	8215	3375000	435.525	19.35667	2434.074
15%	7	1	8535	3375000	344.475	15.31	2528.889
		2	8475	3375000	377.1	16.76	2511.111
		3	8439	3375000	382.725	17.01	2500.444
		mean	8483	3375000	368.1	16.36	2513.481
	28	1	8346	3375000	514.125	22.85	2472.889
		2	8468	3375000	580.05	25.78	2509.037
		3	8339	3375000	554.625	24.65	2470.815
		mean	8384.333	3375000	549.6	24.42667	2484.247
20%	7	1	8580	3375000	397.8	17.68	2542.222
		2	8514	3375000	460.35	20.46	2522.667
		2	8566	3375000	406.3725	18.061	2538.074
		mean	8553.333	3375000	421.5075	18.73367	2534.321
	28	1	8337	3375000	602.55	26.78	2470.222
		2	8475	3375000	676.8	30.08	2511.111
		2	8525	3375000	615.6	27.36	2525.926
		mean	8445.667	3375000	631.65	28.07333	2502.42

Table 3.6 a trial of cement increment for sand having 18% silt and clay.

Cement increment	curing Age	no of sample	weight (gm)	volume of cube(cm3)	Failure load(KN)	comp. strength (Mpa)	Unit weight (kg/m3)
15%	7	1	8386	3375000	281.475	12.51	2484.741
		2	8365	3375000	332.775	14.79	2478.519
		3	8457	3375000	297.675	13.23	2505.778
		mean	8402.667	3375000	303.975	13.51	2489.679
	28	1	8312	3375000	433.125	19.25	2462.815
		2	8332	3375000	475.425	21.13	2468.741
		3	8226	3375000	425.25	18.9	2437.333
		mean	8290	3375000	444.6	19.76	2456.296
20%	7	1	8560	3375000	320.625	14.25	2536.296
		2	8500	3375000	379.125	16.85	2518.519
		3	8464	3375000	353.025	15.69	2507.852
		mean	8508	3375000	350.925	15.59667	2520.889
	28	1	8371	3375000	478.575	21.27	2480.296
		2	8493	3375000	583.2	25.92	2516.444
		3	8364	3375000	569.475	25.31	2478.222
		mean	8409.333	3375000	543.75	24.16667	2491.654
25%	7	1	8605	3375000	434.475	19.31	2549.63
		2	8539	3375000	422.55	18.78	2530.074
		2	8591	3375000	397.215	17.654	2545.481
		mean	8578.333	3375000	418.08	18.58133	2541.728
	28	1	8412	3375000	611.775	27.19	2492.444
		2	8550	3375000	650.025	28.89	2533.333
		2	8600	3375000	575.55	25.58	2548.148
		mean	8520.667	3375000	612.45	27.22	2524.642

Table 3.7 summary of the relation b/n Cement increment for 6% silt/clay content of sand with compressive strength and workability of concrete.

cement increment	curing age(d)	weight(kg)	volume	failure load	ave. comp. strength	Density(kg/m3)	slump(cm)
3%	7	8302.6667	3375000	390.75	17.36666667	2460.049	28
	28	8190	3375000	572.4	25.44	2426.667	
5%	7	8358	3375000	421.5	18.73333333	2476.444	31
	28	8259.3333	3375000	652.71	29.00933333	2447.21	
10%	7	8429	3375000	450.3825	20.017	2497.481	38
	28	8320.6667	3375000	677.1	30.09333333	2465.383	

Table 3.8 summary for the relation b/n Cement increment for 10% silt/clay content of sand with compressive strength and workability of concrete.

cement increment	curing age(d)	weight(kg)	Volume(cm3)	failure load	ave. comp. strength	density(kg/m3))	slump(cm)
5%	7	8293.7	3375000	356.775	15.8566666	2457.38271	16
	28	8181	3375000	509.625	22.65	2424	
10%	7	8349	3375000	387.75	17.2333333	2473.77777	28
	28	8250.3	3375000	564.525	25.09	2444.54321	
15%	7	8419.3	3375000	492.2325	21.877	2494.617284	32
	28	8311.7	3375000	707.25	31.4333333	2462.71604	

Table 3.9 summary of the relation b/n Cement increment for 14% silt/clay content of sand with compressive strength and workability of concrete

cement increment	curing age	weight(kg)	volume	failure load	ave. comp. strength	Density(kg/m3)	slump(cm)
10%	7	8327.667	3375000	297.1875	13.20833	2467.457	17
	28	8215	3375000	435.525	19.35667	2434.074	
15%	7	8483	3375000	368.1	16.36	2513.481	27
	28	8384.333	3375000	549.6	24.42667	2484.247	
20%	7	8553.333	3375000	421.5075	18.73367	2534.321	36
	28	8445.667	3375000	631.65	28.07333	2502.42	

Table 3.10 summary of the relation b/n Cement increment for 18% silt/clay content of sand with compressive strength and workability of concrete.

cement increment	curing age(day	weight(kg)	Volume(cm3	failure load	ave. comp. strength	Density(kg/m3)	Slump(cm)
15%	7	8402.667	3375000	303.975	13.51	2489.679	22
	28	8290	3375000	444.6	19.76	2456.296	
20%	7	8508	3375000	350.925	15.59667	2520.889	31
	28	8409.333	3375000	543.75	24.16667	2491.654	
25%	7	8578.333	3375000	418.08	18.58133	2541.728	43
	28	8520.667	3375000	612.45	27.22	2524.642	

ANNEX -4 Material cost for 1m3 concrete by using different sand

Table 4.1 material cost of 1m3 concrete by using Opc cement and Yedi sand

Material cost	unit	qty	unit price	Amount
Cement	qnt	3.6	400	1440
sand	kg	0.512275152	500	256.137576
aggregate	kg	0.745579572	750	559.1846793
Water	L	192.5	0.0038	0.7315
total cost				2256.053755

Table 4.2 material cost of 1m3 concrete by using ppc cement and Yedi sand

Material cost	unit	qty	unit price	Amount
Cement	qnt	3.6	300	1080
sand	kg	0.512275152	500	256.137576
aggregate	kg	0.745579572	750	559.1846793
Water	L	192.5	0.0038	0.7315
total cost				1896.053755

Table 4.3 material cost of 1m3 concrete by using Opc cement and Asendabo and Nada kela sand.

Material cost	unit	qty	unit price	Amount
Cement	qnt	3.6	400	1440
sand	kg	0.512275152	437	223.864
aggregate	kg	0.745579572	750	559.185
Water	L	192.5	0.0038	0.7315
total cost				2223.78

Table 4.4 Material cost of 1m3 concrete by using ppc cement and Asendabo and Nada kela sand

Material cost	unit	qty	unit price	amount
Cement	qnt	3.6	300	1080
sand	kg	0.512275152	437	223.864
aggregate	kg	0.745579572	750	559.185
Water	L	192.5	0.0038	0.7315
total cost				1863.78

Table 4.5Material cost of 1m3 concrete by using Opc cement and Werabe or chewaka sand

Material cost	unit	qty	unit price	amount
Cement	qnt	3.6	400	1440
sand	kg	0.512275152	875	448.2407579
aggregate	kg	0.745579572	750	559.1846793
Water	L	192.5	0.0038	0.7315
total cost				2448.156937

Table 4.6.Material cost of 1m3 concrete by using ppc cement and Werabe or CHewaka sand

Material cost	unit	qty	unit price	amount
Cement	qnt	3.6	300	1080
sand	kg	0.512275152	875	448.2407579
aggregate	kg	0.745579572	750	559.1846793
Water	L	192.5	0.0038	0.7315
total cost				2088.156937

Table 4.7. Material cost of 1m3 concrete by using opc cement and gambela sand

Material cost	unit	qty	unit price	Amount
Cement	qnt	3.6	400	1440
sand	kg	0.512275152	1000	512.275
aggregate	kg	0.745579572	750	559.185
Water	L	192.5	0.0038	0.7315
total cost				2512.19

Table 4.8. Material cost of 1m3 concrete by using ppc cement and gambela sand

Material cost	unit	qty	unit price	amount
Cement	qnt	3.6	300	1080
sand	kg	0.512275152	1000	512.275
aggregate	kg	0.745579572	750	559.185
Water	L	192.5	0.0038	0.7315
total cost				2152.19

Table 4.8. Material cost of 1m3 concrete by using ppc cement and 30% Asendabo &70% Gambela sand

Material cost	unit	qty	unit price	Amount
cement	qnt	3.6	300	1080
sand	kg	0.512275152	831	425.7006512
aggregate	kg	0.745579572	750	559.1846793
water	L	192.5	0.0038	0.7315
total cost				2065.61683

Table 4.8. Material cost of 1m3 concrete by using ppc cement and 20% Asendabo &80% Chewaka sand

Material cost	unit	qty	unit price	Amount
cement	qnt	3.6	400	1440
sand	kg	0.512275152	800	409.8201215
aggregate	kg	0.745579572	750	559.1846793
water	L	192.5	0.0038	0.7315
total cost				2409.736301