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SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

EFFECT OF CLAYEY SILT CONTENT ON CONCRETE STRENGTH

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Addis Ababa, March 2014

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A thesis submitted to School of Graduate Studies of Addis Ababa institute of technology in partial fulfillment of the requirements for the degree of Master of Science in Structural engineering

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Effect of clayey silt content on concrete strength

MSc thesis

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ABSTRACT

In the present day construction industry in Ethiopia, concrete has emerged as the most common building material. Hence careful consideration must be given to factors that affect its strength. One of the factors affecting the strength of concrete is the amount of clayey silt content of sand used in the mix of concrete. This work (thesis) determines the strength of concrete (compressive, tensile using splitting method and flexural strength) for sand samples with varying percentage of clayey silt content from 0% to 10% for C-25 mix design and the principal aim of this research is to investigate the effects of clayey silt microfine coatings of sand on concrete structures and to use this knowledge to improve the present aggregate monitoring situation in Ethiopia. From the mix design the proportion of materials for concrete is found to be 1:2:4 ratios. The sand sample was collected from a quarry site at Senbo River located in the National States of Oromia, Horu Gudru Welega Zone around Fincha Sugar Factory. The silt content of the quarry sand was tested and found to be 5.05%. The sand sample was divided into five parts (A-E) and in such a way that from each part, 3 cubes (of 150 x 150 x 150 mm^3) each for 3, 7 and 28 days of curing time for compressive strength, 2 cylinder (Φ=150mm and h=300mm) for 7 and 3 cylinders (of the same dimension) for 28 days of curing time for tensile strength and 2 prism (100*100*510mm^3) for 28 days of curing time for flexural strength test was prepared. For 0% silt all of the sand was washed. For 2.5% half of the sand was washed. For 5.05% the quarry sand is used. For 7.5% and 10% the additional silt/clay required was collected from the quarry sand using 75µm sieve so that the required amount 2.45% and 4.95% by weight respectively for each samples were added. The resultant samples of mixture of washed sand and with clay/silt were labeled samples A to E. Sample A contained 0% clay/silt; sample B contained 2.5% of clay/silt and so on. The compressive strength, tensile strength and flexural strength of concrete of each part of sand with varying content of clay/silt from 2.5% to 10% were determined. From the laboratory test result it was discovered that the higher the silt/clay content of sand in the concrete mix, the weaker is the strength of the concrete.

CHAPTER ONE

1.1 INTRODUCTION

Due to the fact that aggregates comprise between 60-80 % of the total volume of concrete; from which about 40 % of the total volume of the aggregate is fine aggregate; and concrete failures have often been tied to the use of different aggregates, it would appear that one should characterize these aggregates and their surface chemistries in order to determine the roll of these materials on the final performance of concrete. Fine aggregates often contain a layer of small particles bound strongly or weakly to the aggregate surface (a surface coating). Previous research associates the presence of some type of micro-fines on the surface of these aggregates with deleterious properties of concrete. A large fraction of micro-fine gravel coatings consist of clay minerals. Due to their small size and large surface areas as well as differing chemistries, these minerals likely can be expected to be major components of reactivity in concrete systems. It has been widely reported that presence of clays in cement reduces the compressive strength and increases shrinkage in the resulting concrete. However, the exact mechanism by which these clays affect these properties has not been established. Thus, when the cement powder is added to this mixture, 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.

CHAPTER TWO

2.1 OBJECTIVE

- To investigate the effect of clayey silt content on the strength of concrete

2.2. General

As the title of the thesis reveals the goal of the research is to investigate the effect of clayey silt content on concrete strength.

Depending on the required services, concrete may made to have properties that comprise strength, elasticity, water tightness, durability and the likes. Concrete strength comprises compressive, tensile and shear strengths. The strength is the ability of the structure to resist the applied forces, elasticity stands for modulus of elasticity and creep. Durability of concrete is the ability of concrete to maintain its quality throughout its designed service life.

Since the primary function of practically all structures is to carry loads or resist applied forces of whatever nature, concrete used for such purposes must have strength. Although in some cases other characteristics may be more important, the strength of concrete is commonly considered as its most valuable property. Therefore, since silt content affects the strength of concrete laboratory tests are important to find out the effect of the percentage of clayey silt with the strength of concrete.

2.2.1. Material and Methodology

The materials used for this experiment were crushed granite rock, with maximum size of 20mm for coarse aggregate. The aggregates were thoroughly washed (to remove unwanted materials) and sun dried; they were graded in accordance with AASHTO M43-88. Natural sand for fine aggregate was obtained from a quarry site at Senbo River located in the National States of Oromia Horu Gudru Welega Zone around Fincha Sugar Factory. The cement used is the brand pozolana Portland cement (PPC) of Derba cement factory. Water used for the tests was free from impurities such as silt, clay, acids, alkalis and other salts, organic matters and sewage. First category of the tests conducted examined the physical properties of the quarry sand and crushed aggregate. These properties are the particle size distribution based on AASHTO M6-93 for fine aggregate and AASHTO M43-88 for coarse aggregate, bulk specific gravity (SSD basis) and mix design for C-25 was prepared. The silt content of the quarry sand was tested and found to be 5.05%. The sand sample was divided into five parts (A-E) in such a way that from each part, three cubes (of 150 x 150 x 150 mm^3) for each 3, 7 and 28 days of curing time for compressive strength, 2 cylinders (of Φ=150mm and h=300mm) for 7 days and 3 cylinders (of the same dimensions) for 28 days of curing time for tensile strength, and 2 prism (of $100*100*510mm^3$) for flexural strength at 28 days of curing time was made for each percentage of clayey silt of the sand. For 0% clayey silt all of the sand was washed. For 2.5% half of the sand was washed. For 5.05% the quarry sand is used. For 7.5% and 10% the additional clayey silt required was collected from the quarry sand using 75µm sieve so that the required amount 2.45% and 4.95% by weight respectively for each samples were added. The resultant samples of mixture of washed sand and with clayey silt were labeled samples A to E. Sample A contained 0% clayey silt; sample B contained 2.53% of clayey silt and so on. The required quantity quarry sand at saturated surface Dry (SSD), cement and coarse aggregate (crushed stone also at SSD condition) as well as water was measured and spread the mixer. The constituents were thoroughly mixed until a good consistency mix was obtained. The slump test was performed on each batch in accordance with provisions of BS 1881 (1996). The specimens were then cast in three layers; each layer was vibrated for 0.3 -0.45 minutes. The top surfaces of the specimens were toweled flat and molded in the laboratory for 24 hours, the concrete cubes, cylinder and beams were demolded and cured by immersion in water in the curing tank. After the above-specified curing days, the concrete samples were tested using Universal Testing Machine and the compressive, tensile and flexural strength of each of these samples were recorded and analyzed.

CHAPTER THREE

LITERATURE REVIEW

3.1 INTRODUCTION

In the last few years, the ability to design alternative methods of producing concrete has greatly expanded but so too has the level of complexity in determining which set of parameters provides superior concrete performance. Several factors contribute to this complexity: the use of different sources of materials (multiples sources of rock, sand and cements), the replacement of cement by new cementitious materials (fly ash, ground granulated blast furnace slag, etc), and the introduction of many new chemical additives that are claimed to produce a superior product. Special significance has been given to the case of aggregates as they comprise between 60- 80 % of the total volume of concrete. It has been well documented that the presence of micro fines on aggregate materials has a significant impact on the ultimate quality of resulting pavements. Defects such as spalling, longitudinal cracking, transverse cracking, and corner breaks have been in large part attributed to presence these micro-fines [8].

3.2 Aggregates

Aggregates are part of a large parent material, which may have been fragmented by a natural process of weathering and abrasion or artificially by crushing. As a result, many properties such as chemical and mineral composition, specific gravity, hardness, strength, physical and chemical stability; colors depend entirely on the properties of the parent rock. These properties are very essential in production of quality concrete. Apart from the properties of the parent material, there are aggregate properties such as grading, shape, surface texture which are very important than the properties of the parent material in producing strong, durable and economical concrete. In a concrete mixture, the aggregates form the inert mineral filler material, which the cement paste binds together. Because the aggregates provide relatively cheap filler, it is advisable to use as much aggregates as a given amount of paste will bind together. In addition to being relatively cheap filler, the aggregates reduce the volume changes resulting from the setting and hardening process and from moisture changes in the paste. Aggregate contributes about 75 % by volume of concrete, creating stability from volume change and by far cheaper than cement, aggregate affects not only the properties of the concrete but also its economy. Thus, care should be given in choosing aggregate in concrete production [4].

Mineral aggregate for concrete aggregate or simply aggregate is more or less inert, granular, usually inorganic material consisting normally stone(s) or stone like solid(s). Typical examples are sand, gravel, crushed stone, and crushed slag.

In compacted hardened concrete, the paste fills the voids between the aggregate particles and bonds them firmly together. That is, the paste holds the aggregate particles together as matrix. Aggregate occupies roughly three-fourth of the volume of concrete, so its quality has a considerable important on the concrete quality. Aggregate is used in concrete because it reduces greatly the needed amount of cement in the mixture, thus decreases the creep and shrinkage of the concrete and, at the same time, makes it cheaper [7].

In ordinary structural concretes, the aggregates occupy 65-75% of the volume of the hardened mass. The remainder consists of hardened cement paste, uncombined water (i.e. water not involved in hydration of cement), and air voids. The latter two do not contribute to the strength of the concrete. In general, the more densely the aggregate can be packed, the better the durability and economy of the concrete. For this reason the gradation of the particle sizes in the aggregate, to produce close packing, is of considerable importance. It is also important that the aggregate have good strength, durability, and weather resistance; that its surface be free from impurities such as loam, clay, silt, and organic matter that may weaken the bond with cement paste; and that no unfavorable chemical reaction take place between it and the cement [2].

The better the gradation of aggregates; i.e. the smaller the volume of voids, the less cement paste is needed to fill these voids. In addition to the water required for hydration, water is needed for wetting the surface of the aggregate. As water is added, the plasticity and fluidity of the mix increased i.e. its workability improves, but the strength decreases because of the larger volume of voids created by the free water. To reduce the free water while retaining the workability, cement must be added. Therefore, as for cement paste, the water-cement ratio is the chief factor that controls the strength of the concrete [2].

3.2.1 Classification of aggregates

Aggregates are generally classified based on their source, their chemical composition, their weight, their size or the mode of preparation.

As regarded the source, aggregates may be natural or artificial. Natural aggregates are obtained from riverbeds (sand, gravel) or from quarries (crushed rock), while artificial aggregates are generally obtained from industrial wastes such as blast furnace slag.

Coarse Aggregates: Coarse aggregates are the material that will be retained on a No. 4 sieve. In determining the maximum size of coarse aggregate, other factors must also be considered. The coarser the aggregate used, the more economical the mix, as aggregate costs less than cement. Larger pieces offer less surface area of the particles than an equivalent volume of small pieces. Using the largest permissible maximum size of coarse aggregate permits a reduction in cement and water requirements. One restriction usually assigned to coarse aggregate is its maximum size. Large pieces can interlock and form arches or obstructions within a concrete form. This restricts the area below to a void or at best, fills the area below with the finer particles of sand and cement. This is either a weakened area or a cement-sand concentration that does not leave enough mortar to coat the rest of the aggregate [17].

Fine Aggregates: Fine aggregates are the material that will pass a No. 4 sieve, and will predominantly retain on a No. 200 sieve. To increase workability and for economy as reflected by using less cement, the fine aggregates should have a rounded shape. Their purpose is to fill the voids between coarse-aggregate particles and to modify the concrete's workability [17].

The sand from river due to natural process of attrition tends to possess smoother surface texture and better shape. It also carries moisture that is trapped in between the particles. These characters make concrete workability better. However, silt and clay carried by river sand can be harmful to the concrete since clay particles have a large surface area per unit volume and can hold more water and nutrients on these surface areas. Changes in water content of some clay give rise to swelling and shrinkage of soil volume which highly affects the strength of the concrete [16].

This can be seen by the presence of cracks which develop as the clay soil dries and shrinks. Add enough moisture and the cracks close, i.e.: the clay swells. Another issue associated with river sand is that of obtaining required grading with a fineness modulus of 2.4 to 3.1.It has been verified and found, at various locations of Ethiopia, that it has become increasingly difficult to get river sand of consistent quality in terms of grading requirements and limited silt / clay content. It is because we do not have any control over the natural process. In case of manufactured sand, the process of attrition through washing makes the crushed stone sand particles good enough to be compared shape and surface texture of natural sand. With well-designed screening system the required grading and fineness modulus (2.4 to 3.1) can also be achieved consistently in the case of manufactured sand. It must be noted that properly processed manufactured sand can improve both compressive strength and flexural strength through better bond compared to river sand. Fine aggregates used for concrete structures have microscopic fines which affects the strength of the concrete [5].

3.3. Types of micro-fines coatings found on fine aggregates

Fine aggregates commonly contain small particles (surface coatings) that are bounded strongly or weakly to the aggregate surface. These fine particles may partially or completely cover the surface of the aggregate. The coating usually appears as layers, blends, patches, or individual grains. The most universal types of coatings are clays, calcium carbonates, and dust or silt. Clay coatings originate by precipitating water-soluble materials from sand or gravel deposits; and are different from the rest of the coatings in that they strongly adhere to the surface of the aggregate. Clay minerals comprise a significant proportion of these finely divided materials and, as we shall also demonstrate, they are already known to cause deleterious effects in concrete [8].

3.3.1. Brief definition of clays

Micro-fine materials in concrete are defined as those able to pass through No. 200 sieve (75 μm). This fraction of material is normally found as a part of the fine aggregates used in concrete production. The mineralogy of these micro-fines has been studied for a long time. They could be classified into three major types: stone dust, clay minerals, or calcium carbonate. A recent study performed university of Wisconsin, found that common mineralogy of micro-fines falls under the previous classifications, and the clays are the fraction with higher deleterious potential. The characteristics of the clay fraction vary depending on the type of clay mineral. For example, some types of clay are held so tightly to the aggregate surface that they may not be displaced during washing, while other types of clay may be released into the water and are removed during aggregate washing or concrete mixing. Therefore, the effects of clays in concrete can be located in two different areas. First clay minerals, which weakly adhere to aggregates, will be dispersed in the mixing water and therefore will be integrated in the cement paste. Second, those types of clay minerals that are strongly bonded to the aggregate surface will remain mostly located at the aggregate surface after the mixing process and therefore may disrupt the aggregate-cement paste bond [8].

As noted from researchers in University of Wisconsin-Madison (Jose F Muñoz ea.) depending on the chemical composition clay can be grouped in to four types which are Kaolin, Illite,Na-M and Ca-M as shown in table1 below

Table1. Chemical composition in percentage of the clays

clay	SiO_2	A_2O_3	TiO2	Fe_2O_2	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	S	F
Kaolin	43.9	38.5	2.08	0.98	0.15	--	0.03	--	0.065	0.065	0.045	0.02	--
Illite	49.3	24.25	0.55	7.32	0.55	0.03	2.56	0.43	0	7.83	0.08	--	--
Na-M	62.9	19.6	0.09	3.35	0.32	0.006	3.05	1.68	1.53	0.53	0.049	0.05	0.11
Ca-M	62.9	19.6	0.09	3.35	0.32	0.006	3.05	1.68	1.53	0.53	0.049	0.05	0.11

Clay minerals are phyllosilicates of small particle size (< 2 μm). They are formed by combining two basic sheet structures: one is a continuous two-dimensional tetrahedral sheet of individual tetrahedron sharing three corners and the fourth pointing in any direction. The central atom of the tetrahedron could be Si or Si/Al. The second sheet is an octahedral sheet built of octahedrons shearing edges with Al3+, Mg2+ or Fe3+as the central atom. The different combinations of octahedral and tetrahedral sheets, that form the unit layer of the clay, generate different types of clays: when the unit layer is comprised of one tetrahedral sheet and one octahedral sheet the clay is classified as a 1:1 layer silicate; if the unit layer of the clay consists of two outer tetrahedral sheets and an inner octahedral sheet the clay is classified as *2:1* layer silicate. Negative charge development on silicate clays is mainly due to isomorphous substitution in either sheet. In tetrahedral coordination, Al3+ substitutes for Si4+ and in octahedral coordination Mg2+, Fe2+, Fe3+ ions substitute for Al3+. When the intra-layer charge balance of the 2:1 type silicates is incomplete, the net charge deficit is balanced by alkaline and alkaline earth cations situated between the layers. These cations can be easily exchanged [8].

3.3.2. Clayey silt particles of sand

Sand is a product of natural or artificial disintegration of rocks and minerals. Sand is obtained from glacial, river, lake, marine, residual and wind-blown (very fine sand) deposits. These deposits, however, do not provide pure sand. They often contain other materials such as dust, loam and clay that are finer than sand. The presence of such materials in sand used to make concrete or mortar decreases the bond between the material to be bound together and hence the strength of the mixture. The finer particles do not only decrease the strength but also the quality of the mixture produced resulting in fast deterioration [9].

For good quality concrete, dust or clayey matter should not be present in excessive quantities on the surfaces of the aggregate particles; otherwise the bond between the aggregate particles and the cement paste may be reduced [1, 3, 4, 15].

Presence of dust (silt and clay) in aggregates can reduce the compressive strength of concrete by as much as 52% at 30% content and as much as 57% at 52% content. This result shows that significant increase in dust content has minimal impact on the percentage reduction of concrete compressive strength. To explain this behavior, it is pertinent to note that dust decreases the strength of concrete by two mechanisms: by reducing the bond between cement paste and aggregate, and by increasing the water requirement of the concrete which results in increased water to cement ratio. However, as the dust content of the concrete rises to some certain level, the reduction in bond strength decreases. In addition, although water requirement continues to rise as dust content increases, it is known, Kong and Evans [19] that as water/cement ratio increases to about 0.7, strength of concrete rapidly decreases but as this ratio increases beyond 0.7, the strength of concrete begins to decrease more gradually. The magnitude of reduction in the strength of concrete with increase in dust content depends on the type of coarse aggregate used.

3.3.3. Effects of clayey silt in mixing water

As it was mentioned some of the clay coatings can remain attached to surface of the aggregate after washing or mixing, and therefore they can modify the bond between aggregates and cement paste. Especially if clays have high water adsorption capacity, significant amounts of water can be retained in the surface of the aggregates and increase the porosity of the interface between aggregates and cement paste. The porosity of this particular area has an influence on the durability of concrete. As an example, in severe marine environments, a porosity and weak zone between the aggregate and cement paste will improve the access of water and the intrusion of harmful ions into the concrete matrix [8].

3.3.4. Effect of clayey silt in concrete

Many scientists have investigated the interaction of clays and cement as pozzolanic additives. These studies have revealed that the presence of some type of clays in the cement mixture produce a decrease in the strength and an increase in shrinkage. For example, Unikowski, found that the water demand, for making a workable cement mixture was related to the specific surface area of the clays present in the cement. He noted that a 3 % replacement of sand for montmorillonite decreased the compressive strength by nearly 40 % and doubled the amount of shrinkage. Pike theorized that the loss of strength in clay-mortars was caused by clays adsorbing part of the water used for the cement forming “impermeable envelopes” around the cement grains slowing the rate of the pozzolanic reactions.

It can be concluded that most of the authors believe that a significant amount of clay in a cement mixture reduces the amount of water available for the hydration reactions and thereby decreases its workability and also alters the course of the pozzolanic reactions. As a result, hardened cement containing clay minerals is expected to have different physical properties from that of cement fabricated without clays. It has been widely reported that presence of clays in cement reduces the compressive strength and increases shrinkage in the resulting concrete [8].

Aggregates with varying mineralogical composition produce concretes of diverse characteristics. The type of aggregate affects the strength and the stiffness and long-term deformations of hardened concrete. For example, some aggregates may react negatively with cement or, on the contrary, they may interact beneficially with paste, enhancing strength or stiffness. As a result, elastic modulus, creep, or shrinkage can vary as much as 100 percent depending on aggregate type. The type of aggregate also affects the interfacial transition zone, ITZ, which has an effect on strength and stiffness of concrete. Finally, the type of aggregate influences the abrasion resistance of concrete, particularly of high-strength concrete [14].

Coatings, the layers of material covering the surface of aggregate, can increase the demand for water and can impair the bond between paste and particles. Sometimes these coatings are formed by materials that can interact chemically with cement, negatively affecting concrete [14].

These four clays (NaM, CaM, Kaolin and illite) present very different hydration properties and cation exchange capacities (CEC), as seen in Table 2. Kaolin and illite have a smaller and medium water absorption capacity, respectively. Both CaM and NaM have a large capacity to absorb water and swell. The NaM when immersed in water suffers a destacking process, in other words, individual silicate layers separate from each other. The CaM only has a crystalline swelling process where the water is able to enter principally in between the layers that formed the structure of the particles. Finally, illite and kaolin are clays with very low water adsorption capacity and do not suffered crystalline swelling. The clay with macroscopic swelling (NaM) is the most difficult to detach and decreases the rate of hydration. Clays with crystalline swelling (CaM) and no swelling (kaolin) are easier to detach and increase the rate of the hydration reactions. Clays with higher Cation Exchange Capacity (Na and Ca montmorillonite) produce the higher impacts in fresh and hardened concrete properties. Montmorillonite group clays, tended to adsorb high amounts of water and increase the stiffness of the plastic concrete mixtures. This stiffness in the mixture inhibits adhesion between cement paste and coarse aggregate. These effects lead to concretes with lower compressive and tensile strengths, and higher shrinkage and lower freeze-thaw durability. In contrast, one of the clays with low CEC (kaolin) only affected workability by decreasing the slump. The other clay, illite, did not affect workability [8].

Table2 Characteristics of clay

Clay	CEC(meg/100g)	Hydration process
Na-M	74-79	Macroscopic swelling
Ca-M	74-79	High crystalline swelling
Illite	15	No crystalline swelling
Kaolin	1.7-2.4	no crystalline swelling

The exchangeable cations in vermiculite and smectite type clays in the presence of water hydrate resulting in an increase in the space between clay layers. This phenomenon is known as the swelling of the clay. The amount of absorbed water in air is a function of the relative humidity and also of the quantity and nature of the exchangeable cations present in the clay. When these clays are immersed in water they can react in two different ways:

Endure crystalline swelling: the maximum expansion of the basal space in the clay is equal to that experienced in air at 100 % RH. For example, smectites, its basal spacing when dehydrated is between 0.95 to 1.00 nm, upon hydration, passes to 1.9 nm.

Suffer macroscopic swelling: In the case of some clay, the basal spacing's reach values larger than 4.0 nm upon their immersion in water. In this case, the unit layers start to separate from each other and the clay particles are said to be destacked or exfoliated. A clear example of this type of behavior is Na and Li smectites. In water or dilute solutions, these systems can swell macroscopically into a gel-like state in which the average layer separation is greater than 4.0 nm and increases in proportion to 1/Öc, where c is the electrolyte concentration in the liquid phase. This phenomenon is associated with the formation of a diffuse electrical double layer on each surface of the structural layer of the silicate [8].

CHAPTER FOUR

EXPERIMENTAL INVESTIGATION

This investigation aims at studying the effect of silt/clay content on the strength of concrete which includes compressive, tensile and flexural strengths.

4.1 Mix design

Mix design is the proportion of ingredients that would produce a workable concrete mix that is durable and of required strength and at a minimum cost.

4.1.1 Quality concrete: mix design of concrete is very helpful to achieve better strength, durability, homogenous and impervious structures by deciding the relative proportions of ingredients of concrete having in mind that the fresh concrete is workable

4.1.2 Economy

Cement consumption: Due to the high price of cement mix design helps to save cement quantity and lower cement content also results in lower heat of hydration and hence reduces shrinkage cracks.

Best use of available materials: Site conditions often restrict the quality and quantity of ingredient materials. Concrete mix design offers a lot of flexibility on type of aggregates to be used in the mix design. Mix design can give an economical solution based on the available materials if they meet the specification requirements. This can lead to save in transportation costs from longer distances [6].

4.1.3 Sieve analysis

In the construction industry of Ethiopia the manuals used for the sieve analysis and other laboratory tests are AASHTO and ASTM and therefore I used these manuals for particle size distribution of aggregates.

4.1.3.1 Sand

River sand is used and sieve analysis was carried out to whether it meets the AASHTO or BS standards and the result is given in table1 below.

Table 1: Particle size distribution of natural sand AASHTO M 6-93 Or ASTM C 136

Weight Before washing	**Sample 1**						
	5000						
AASHTO Sieve Size mm	Weight Retained	%. Retained	% pass	AASHTO M-6		BS 882	
				Lower	Upper	Lower	Upper
9.5	45.0	0.9	**99.1**	100	100.0	100	100.0
4.75	182.0	3.6	**95.5**	95	100.0	89.0	100.0
2.36	462	9.2	**86.2**	80	100.0	60.0	100.0
1.18	937	18.7	**67.5**	50	85.0	30.0	100.0
0.600	1137	22.7	**44.7**	25	60.0	15.0	100.0
0.300	1289	25.8	**19.0**	10	30.0	5.0	70.0
0.150	711	14.2	**4.7**	2	10.0	0.0	15.0
0.075	187	3.7	**1.0**				
Passing 0.075(pan)	50.0	1.0	**0.0**				
Total Sum	5000.0	100.00		**FM**	**2.83**		

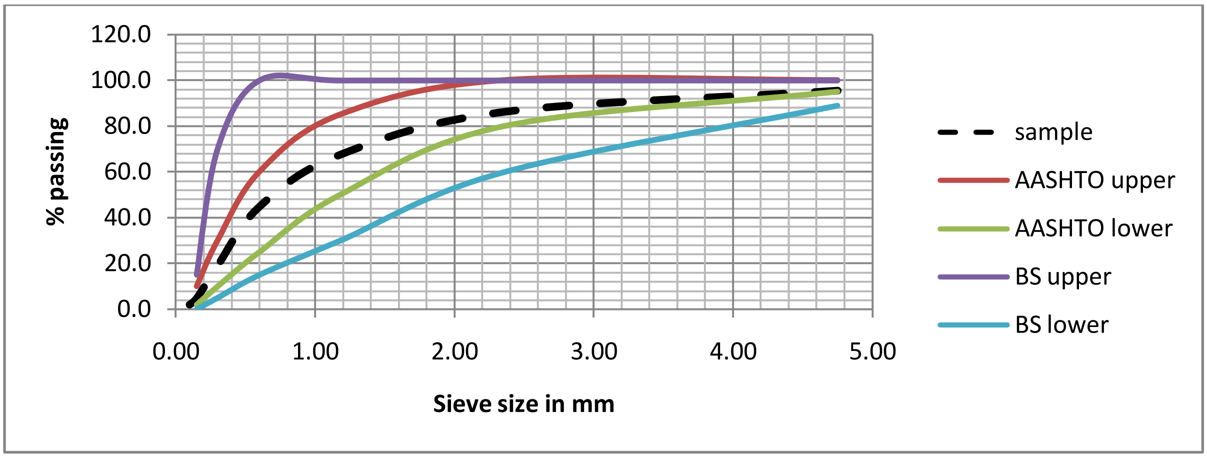


Figure1: Particle size distribution of sand

As can be is seen from the above figure the gradation of sample of sand used is within the upper and lower limit of the standards. It is therefore satisfactory to be used for the concrete preparation

4.1.3.2 Aggregate

A crushed aggregate of maximum size 20mm is used. Two sizes of aggregates (6-12.5 and 12.5-19.5mm) were blend and sieve analysis was carried out and proportioned to meet the AASHTO or ERA standards and the result is given in table 2 below.

Table 2: Particle size distribution of Crushed aggregate (6-12.5mm) AASHTO M43-88/ ASTM C 136

Weight Before washing	**Sample 1**			**Sample2**			
	5069			**4882**			
AASHTO Sieve Size mm	weight Retained	% Retained	% pass	weight Retained	%. Retained	% pass	**% pass Ave**
19.0	0	0.0	100.0	0.0	0.0	100	**100.0**
10.00	207.2	4.1	95.9	209.2	4.3	95.7	**95.8**
4.75	4354.3	85.9	10.0	4171.4	85.4	10.3	**10.1**
0.075	492.1	9.7	0.3	442.6	9.1	1.2	**0.8**
Passing 0.075(pan)	15.4	0.3	0.0	58.8	1.2	0.0	**0.0**
Total Sum	5069	100.00		4882.00	100.00		

Table 3: Particle size distribution of Crushed aggregate (12.5-19.5mm) AASHTO M43-88/ ASTM C136

Weight Before washing	**Sample 1**			**Sample2**			
	6104			**5693**			
AASHTO Sieve Size mm	Weight Retained	%. Retained	% pass	Weight Retained	%.Retained	% pass	**% pass Ave**
25	0	0.0	100.0	0	0.0	100	**100.0**
19.0	294.4	4.8	95.2	135.4	2.4	97.6	**96.4**
10.00	5518.1	90.4	4.8	5193.7	91.2	6.4	**5.6**
4.75	273.7	4.5	0.3	356.5	6.3	0.1	**0.2**
0.075	15.1	0.2	0.0	1.0	0.0	0.1	**0.1**
Passing 0.075(pan)	2.7	0.0	0.0	6.4	0.1	0.0	**0.0**
Total Sum	6104	100.00		5693.00	100.00		

Table 4: combined gradation of coarse aggregate AASHTO N43-88 OR ASTM C 136

AASHTO Sieve Size mm	%pass of 12.5-19.5mm Aggregate	%pass of 6-12.5mm Aggregate	Combined result %	Specification ERA STS 8402-3		AASHTO M43-88	
				Lower	Upper	Lower	Upper
25	100.0	100.0	**100.0**	100	100	100	100.0
19.0	96.4	100.0	**97.3**	80	100	90	100.0
10.00	5.6	95.8	**28.1**	10	40	20	55.0
4.75	0.2	10.1	**2.7**	0	4	0	10.0
0.075	0.1	0.8	**0.2**	0	0.5	0	5.0
%proportion	75.0	25.0	100.0				

As can be is seen from the above figure the gradation of sample of crushed aggregate used is within the upper and lower limit of the standards. It is therefore satisfactory to be used for the concrete preparation

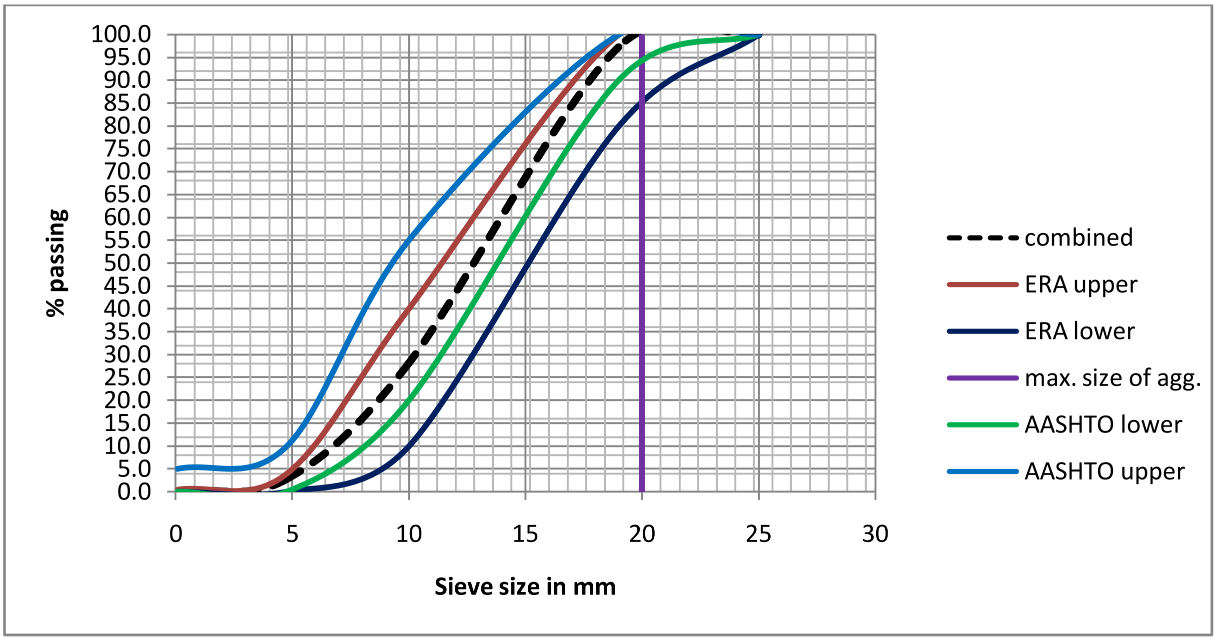


Figure 2: particle size distribution of aggregate

4.1.4 Specific gravity

The specific gravity of a substance is the ratio between the weight of the substance and that of the same volume of water. This definition assumes that the substance is solid throughout. Aggregates, however, have pores that are both permeable and impermeable; whose structure (size, number, and continuity pattern) affects water absorption, permeability, and specific gravity of the aggregates [9, 13].

4.1.4.1 Specific gravity of fine aggregates

The specific gravity of the fine aggregate was determined using 3 different pycnometers so that the average can be taken. For each test, 500gm of oven dried fine aggregate was used. The result is presented in Table 5.

Table 5: specific gravity of fine aggregate (sand)

Trial No.	Mass of dry sand sample in gm (A)	Mass of pycnometer + water in gm (B)	Mass of pycnomete +water + sand in gm (C)	Specific gravity [A/(A+B-C)]
1	500	1262	1576	2.688
2	500	1265	1571	2.577
3	500	1262	1571	2.618
average				2.627

4.1.4.2 Specific gravity of coarse aggregate

The specific gravity of the coarse aggregates was determined using displacement method. First, approximately 2kg of coarse aggregate sample was taken and submerged in water for 24 hours. The aggregates were then taken out and their surface was dried using a towel to remove the excess moisture. After determining their masses, the aggregates were carefully immersed into a beaker filled with water, after which volume of the displaced water was measured. The results obtained for aggregates (6-12.5mm) and (12.5-19.5) are shown in Table 6 and table 7 respectively.

Table 6: Specific gravity of coarse aggregate (6-12.5mm)

Coarse aggregate	SSD mass(gm)	Volume of displaced water	Specific gravity
Sample 1	1760	610	2.88
Sample 2	1658	632	2.62
Average			2.75

Table 7: specific gravity of coarse aggregate (12.5-19.5)

Coarse aggregate	SSD mass(gm)	Volume of displaced water	Specific gravity
Sample 1	1635	604	2.70
Sample 2	1821	639	2.85
Average			2.78

Table 8: Specific gravity and unit weight of materials

Material	Bulk specific gravity (SSD basis)	Unit weight
cement	3.15	1400
Natural sand	2.627	1365
Crushed aggregate (6-12.5mm)	2.75	1392
Crushed aggregate (12.5-19.5mm)	2.78	1439

4.1.5. Silt content of sand

Silt content of the sand to be used in the mix was determined using the following steps (2)

A sample of fine aggregate was taken and it was dried in an oven at 105^{o}c for 24 hours. The material was weighed and its mass was found to be 486.3gm (m1). It was then thoroughly washed on a 75µm sieve until clear water comes out, and again dried in oven at 105^{o}c for another 24 hours. Its final mass was then taken and it was found to be 462.65gm (m^2). The silt content was then calculated as:

Silt content = $\frac{(m1-m2)}{m1} * 100$ = $\frac{(486.3-462.65)}{486.3} * 100$= 5.05

For 0% the sand is thoroughly washed and dried to saturated surface dry (SSD) condition. And for 2.5% silt content of sand half of the mass of sand used for the mix is washed and dried to saturated surface dry (SSD) condition

4.1.6. Adjusted mass of materials to be used in the mix

Table 9: Adjusted mass of materials per m^3 of concrete

material	mass	volume
Aggregate 6.5-12.5mm	329.823	119.797
Aggregate 12.5-19.5mm	989.469	355.387
Natural Sand	565.411	215.230
Cement	360.0	114.286
Water	172.800	172.800
Air		22.500
Estimated Concrete Density	2417.503	1000.000

The volume of concrete for one mix of each of A-E (0%, 2.5%, 5%, 7.5% and 10%) i.e. 9 cubes, 5 cylinder and 2 beam is **0.0738 m^3** therefore the mass of each materials for each mix is as shown in table 10.

Table 10: quantities of material used for each mix

material	mass
Aggregate 6.5-12.5mm	24.3
Aggregate 12.5-19.5mm	73.0
Natural Sand	41.7
Cement	26.6
Water	12.7

Since the natural sand is with a silt/clay content of 5.05% the amount of silt collected for a mix with a silt/clay content of 7.5 and 10 passing 75µm is shown in table 11.

Table 11: quantity of silt/ clay collected

% of silt	Silt collected
7.5	1.043
10	2.086

Table 12: Washed and unwashed sand prepared for each mix

% of silt/clay	**Natural Sand (kg)**	
	washed	**unwashed**
0	41.7	0
2.53	20.86	20.86
5.05	0	41.7
7.55	0	40.67
10.05	0	39.63

Table 13: Actual mass of ingredients for each mix prepared

% of silt/ clay	Natural sand		Crushed Aggregate		cement	water
	washed	unwashed	6-12.5mm	12.5-19.5mm		
0	41.7	0	24.3	73	26.6	12.7
2.5	20.86	20.86	24.3	73	26.6	12.7
5.0	0	41.7	24.3	73	26.6	12.7
7.5	0	40.67	24.3	73	26.6	12.7
10.0	0	39.63	24.3	73	26.6	12.7

4.2 Test procedure

4.2.1 Slump test

A concrete mix ,either produced at a ready mix plant or on site, must be made of the right amount of cement, aggregate and water to make the concrete workable enough for easy compaction and placing and strong enough for good performance in resisting stress after hardening. If the mix is too dry, then its compaction will be too difficult and if the concrete is too wet, the concrete is likely to be weak.

During mixing the mix might vary without the change very noticeable at first. For instance, a load of aggregate may be wetter or drier than that is expected or there may be variations in the amount of water added to the mix. These all necessitate a check on the workability and strength of concrete after producing.

Slump test is the simplest for workability and is most widely used on construction sites. In the slump test, the distance that a cone full of concrete slumps down is measured when the cone is lifted from around the concrete. The slump can vary from nil on dry mixes to complete collapse on very wet ones. One drawback with this test is that it is not helpful for very dry mixes.

There are three kinds of slumps

1. True slump- where the concrete just subsides, keeping its shape approximately
2. Shear slump – where the top half of the cone shears off and slips sideways down an inclined plane
3. Collapse slump – where the concrete collapses completely

The first one is associated with workable mix while the other two are usually associated with harsh mixes that lack cohesion [9].

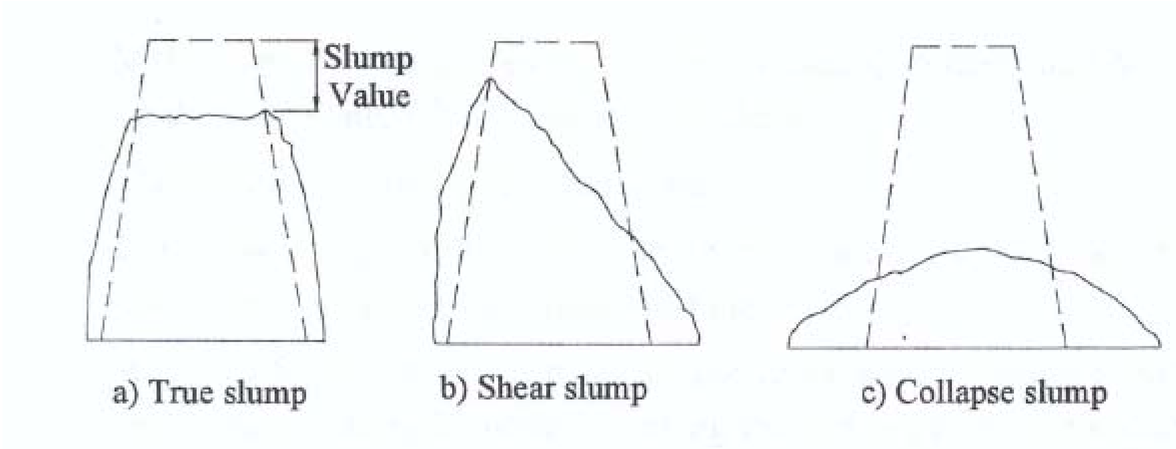


Figure 3: kinds of slumps

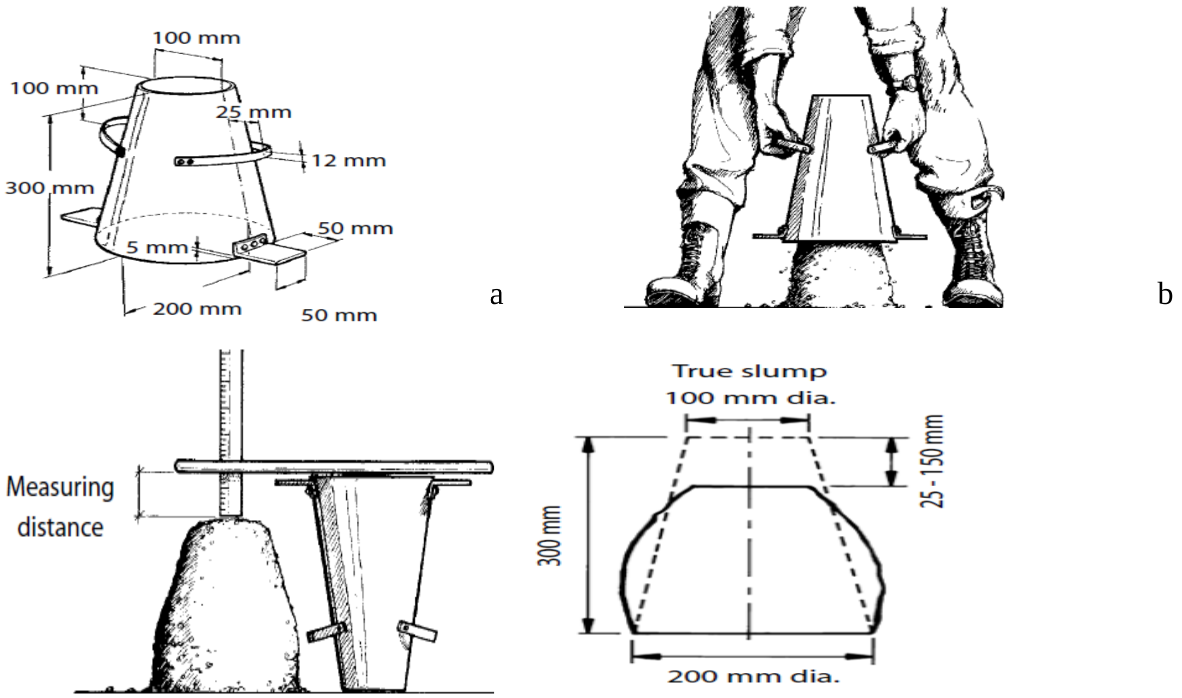
4.2.1.1 Apparatus used

- Standard slump cone – 300mm high with a bottom diameter of 200mm and top diameter of 100mm
- A steel tamping rod, 600 mm long with a diameter of 16 mm that has at least one end rounded
- Measuring tape or ruler
- Steel float
- Water proof base plate, about 450*450mm square
- Cleaning rags

4.2.1.2 Procedures

1. Make sure the cone is clean, free from hardened concrete and dry inside. Stand it on the base plate, which must also be clean.
2. Stand with your feet on the foot rests.
3. Using the scoop fill the cone to about one-third of its height and rod this layer of concrete exactly 25 times using the tamping rod.

4. Add two further layers of equal height (each about 100mm deep), rodding each one in turn exactly 25 times, allowing the rod to penetrate through in to the layer below. After rodding the top layer make sure that there is a slight surcharge of the concrete, i.e. that some concrete sticks out of the top.
5. Strike off the surplus concrete using steel float.
6. Wipe the cone and the base plate clean keeping your feet still on the foot rests.
7. Take hold of the handles and pushing downwards remove your feet from the foot rests.
8. Very carefully lift the cone straight up, turn it over and put it down on the base plate next to the mound of concrete. As soon as the cone is lifted the concrete will slump to some extent.
9. Rest the tamping rod across the top of the empty inverted cone so that it reaches over the slumped concrete.
10. Using the ruler measure from the underside of the rod to the highest point of the concrete, to the nearest 5mm. that will be the slump. (see figure 3,c)
11. If you don’t get a true slump, repeat the test. If the slump is still not normal, ask for advice. (see figure 3,d) [9, 12].



a b c d

Figure 4: slump test procedures

4.2.2 Compressive strength

The major goal of concrete structure is carrying loads coming to them. These loads may be dead, live, earthquake, wind or snow types or their combination. The concrete produced, therefore, must not fail under the action of any of such loads.

The most common test for hardened concrete involves taking a sample of fresh concrete and putting it into a special cube molds so that, when hard, the cubes can be tested to failure in a special machine in order to measure the strength of concrete.

The results obtained from compression tests on hardened concrete cubes are used to check that its strength is above the minimum specified and to assess the control exercised over the production of concrete.

The strength of concrete specimen is affected by factors water-cement ratio, degree of compaction and curing temperature. Care should be taken, therefore, in preparing samples for testing. As water-cement ratio goes up above a certain level the strength will decrease accordingly. Compaction reduces the amount of entrapped air and therefore increases the strength of concrete (for each 1% air entrapped there will be a 5 to 6% loss of strength). Curing temperature affects the hydration of cement and hence the duration of the strength gain (cubes kept at about 10^{o}c will have their 7-day strength reduced by 30% and their 28-day strength reduced by 15%). This calls for proper cure of test cubes at a recommended temperature 20^{0}c [9].

4.2.2.1 Apparatus used

- Mixer
- Cubical mold (15*15*15)cm^3
- Vibrator
- Spatula
- Compressive strength testing machine

4.2.2.2 Procedures

1. A cubical molds (15*15*15) cm^3 are prepared and oiled in order to easily demolding of the concrete molds.
2. The same concrete mix is used for each percentage of silt content for which workability is determined
3. The cubical molds were filled with concrete and vibrated in order to remove air bubbles for about 30sec for single cube and 45sec for double cube molds.

4. The surface of the molded concrete is smoothed and excess concrete on the cubes was removed by spatula, and the mixing date is registered on the top of the concrete.
5. The concrete is removed from the molds after 24hrs and cured in water till the required date.
6. The concrete specimens were loaded to failure at 3,7,28 days of curing time by using testing machine and the failure loads were recorded.
7. The stresses at failure (compressive strength) were calculated by dividing the failure load by the respective contact area of the specimen with the load [9].

4.2.2.3 Calculation

$$\sigma = \frac{p}{b * d}$$

Where,

$\sigma =$ Compressive strength (Mpa)

$p =$Maximum applied load (kN)

$b =$Breadth (m)

$d =$Width (m)

4.2.3 Tensile strength

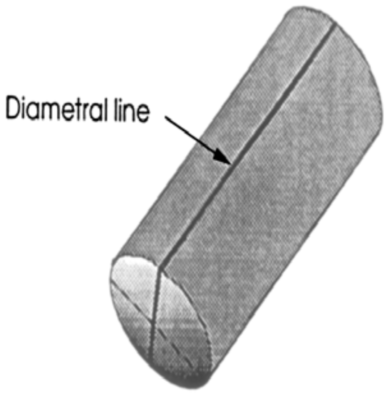
Although concrete is not normally designed to resist direct tension, the knowledge of tensile strength is of value in estimating the load under which cracking will develop. The absence of cracking is of considerable importance in maintaining the continuity of a concrete structure and in many cases in the prevention of corrosion of reinforcement. There are two types of test for strength in tension: direct tension test and splitting tension test [9].

4.2.3.1 Direct tension test

It is the application of pure tension force free from eccentricity, although it is very difficult but some success with the use of lazy-tong grips has been achieved. It is difficult to avoid secondary stress such as those induced by grips or by embedded studs [9].

2.2.3.2 Splitting tension test

In this test, a concrete cylinder, of the type used for compression tests, is placed with its axis horizontal between a plates of the testing machine, and the load is increased until failure by indirect tension in the form of splitting along the vertical diameter takes place. However, immediately under the load a high compressive stress would be induced and, in practice, narrow strips of packing material, such as plywood are interposed between the cylinder and the plates. Without packing strips, the strength is lower, typically by 8 percent. With such an arrangement, the distribution of the horizontal stress will be almost uniform [9].



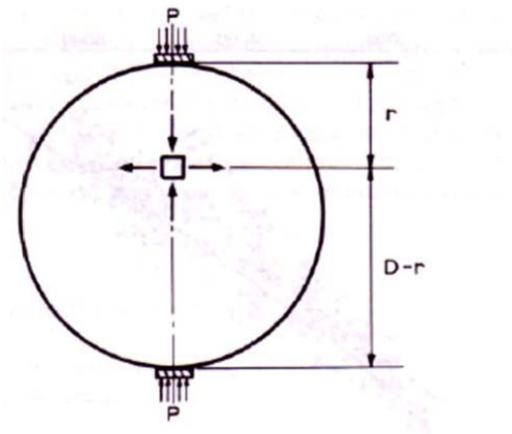


Figure 5: test on tensile strength of concrete

4.2.3.3 Apparatus

- Testing machine
- Bearing strips- two bearing strips of nominal 3mm thick plywood, free of imperfections, approximately 25mm wide and of length equal to or slightly longer than that of the specimen shall be placed between the specimen and both the upper and lower bearing blocks of the testing machine.
- Test specimens
- The test specimen is cylindrical with diameter 15cm and height 30cm.

4.2.3.4 Procedure

1. Diameter lines were drawn on each end of the using suitable device that insured that they were in the same axis plane.
2. The diameters of the test specimen were measured determined by averaging three diameters measured near the ends and middle of the specimen lying in the plane containing the lines marked on the two ends.
3. The length of the specimen was determined by averaging the two lengths measurements taken in the plane containing the lines marked on the two ends.
4. One of the plywood strips was centered along the center of the lower bearing block. The specimen was placed on the plywood strip and aligned so that the lines marked on the ends of the specimen are vertical and centered over the plywood strip.
5. The second plywood was placed on the cylinder lengthwise centered on the lines marked on the ends of the cylinder.
6. A load was applied continuously and without shock at a constant range until failure of the specimen. The maximum applied load was recorded and the type of failure and the appearance of the concrete were noted [9].

4.2.3.5 Calculation

$$\sigma = \frac{2*p}{\pi l d}$$

Where,

σ =Splitting tensile strength (kN/m^2)

p =Maximum applied load (KN)

l =Length (m)

d =Diameter (m)

4.2.4 Flexural strength

Flexural strength is one measure of the tensile strength of concrete. It is measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 6*6inch (150*150mm) concrete beams with a span length at least three times the depth which is 510mm in this research. The flexural strength is expressed as modulus of rupture (MR) in psi (MPa) and is determined by standard test methods ASTM C 78 (third-point loading) or ASTM C 293(center point loading).

Flexural MR is about 10 to 20 percent of compressive strength depending on the type, size and volume of coarse aggregate used. However, the best correlation for specific materials is obtained by laboratory tests for given materials and mix design. MR determined by third-point loading is lower than MR determined by center point loading, sometimes by as much as 15%.

Designers of pavement use a theory based on flexural strength. Therefore, laboratory mix design based on flexural strength tests may be required, or a cemetious material content may be selected from past experience to obtain the needed design MR. some also use MR for field control and acceptance of pavements. Very few use flexural testing for structural concrete. Agencies not using flexural strength for field control generally find the use of compressive strength convenient and reliable to judge the quality of the concrete [10].

During pure bending, the member resisting the action is subjected to internal actions or stresses (shear, tensile and compressive). For a bending force applied downward on a member supported simply at its two ends, fibers above the neutral axis are, generally, subjected to compressive stresses and those below the neutral axis to tensile stresses. For this load and support system, portion of the member near the supports are subjected to relatively higher shear stresses than tensile stresses.

In this test the concrete member to be tested is supported at its ends and loaded at its interior location(s) by a gradually increasing load to failure. The failure load (loading value at which the concrete cracks heavily) is then recorded and used to determine the tensile stress at which the member failed, i.e. its tensile strength [9].

4.2.4.1 Center point loading

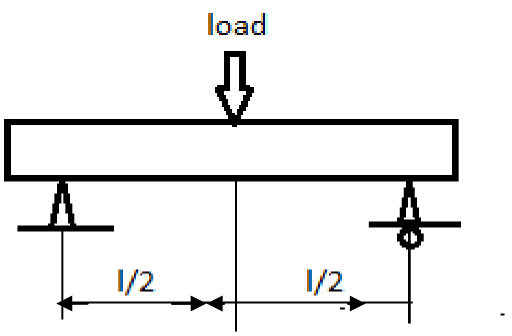


Figure 6: flexural strength testing by center point loading

4.2.4.1.1 Apparatus

- Measuring tape
- Testing machine

4.2.4.1.2 Procedure

1. (50*10*10) cm^3 molds were made ready for test and oiled their insides to be demolded them easily for curing outside the mold.
2. The same mix of concrete is used for each percentage of silt content.
3. The beam molds were filled with concrete and vibrated in order to remove air bubbles for about 45sec.
4. The concrete was demolded after 24hrs and cured for 28 days.
5. The specimen in bending was loaded at its center using bending test machine gradually increasing the bending load to failure.
6. The failure load was recorded and it was used to calculate the flexural stress [9].

4.2.4.1.3 Calculation

$$c = \frac{d}{2} \text{ cm;}$$

$$M = \frac{PL}{4} \text{ Nm;}$$

$$\text{I} = \frac{bd^2}{12} m^4 \text{ ;}$$

$$\sigma = \frac{Mc}{I} \; MPa = 1.5\frac{PL}{bd^3}$$

P= Failure load　　σ =bending strength

M = Maximum moment　　L =span of specimen

I = Moment of inertia　　d =depth of specimen

c = Centroidal depth　　b =width of specimen

4.2.3.2 third-point loading

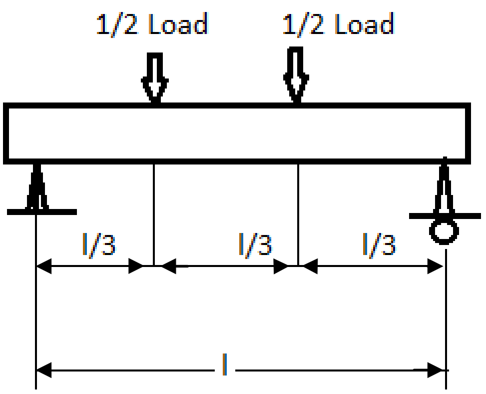


Figure 7: flexural strength testing by third point loading

CHAPTER FIVE

RESULT AND DISCUSSION

5.1 RESULTS

5.1.1 Results of slump test

The results of slump test is shown in table 14 below

Table 14: Slump and water used for each % of silt

% of silt/ clay	Slump	Amount of water used	W/C ratio
0	26	12.7	0.48
2.5	25	12.7	0.48
5	25	13	0.49
7.5	25	13.5	0.51
10	25	14.2	0.53

5.1.1 Result of test for Compressive strength

The results of the experiments on the compressive strength, tensile strength and flexural strength of concrete with the percentage increase of silt/clay content of sand from 0% to 10% are shown in tables 15, 17 and 19 and graphs of their respective values in figures 6, 7, and 8 respectively.

Table 15: Results of Compressive strength of concrete with percentage change of silt/clay content of sand

percentage of silt	sample	compressive strength at Curing time		
		3	**7**	**28**
0	1	17.68	26.08	_
	2	17.93	26.54	37.86
	3	17.52	25.42	36.17
	Average	**17.710**	**26.012**	**37.013**
2.5	1	14.36	21.25	32.00
	2	14.14	21.16	32.62
	3	14.20	21.14	32.67
	Average	**14.237**	**21.182**	**32.430**
5	1	13.79	21.66	29.74
	2	13.67	20.92	30.89
	3	13.40	20.37	29.94
	Average	**13.621**	**20.984**	**30.191**
7.5	1	13.58	20.45	28.88
	2	12.11	20.61	28.96
	3	13.20	19.79	28.24
	Average	**12.964**	**20.284**	**28.689**
10	1	rejected	14.52	21.00
	2	8.84	14.55	21.64
	3	8.81	14.78	21.67
	Average	**8.822**	**14.613**	**21.440**

Table 16: summary of average compressive strength of concrete with percentage change of silt/clay content of sand

percentage of silt	Average compressive strength		
	curing time		
	3	**7**	**28**
0	17.71	26.01	37.01
2.5	14.24	21.18	32.43
5	13.62	20.98	30.19
7.5	12.96	20.28	28.69
10	8.82	14.61	21.44

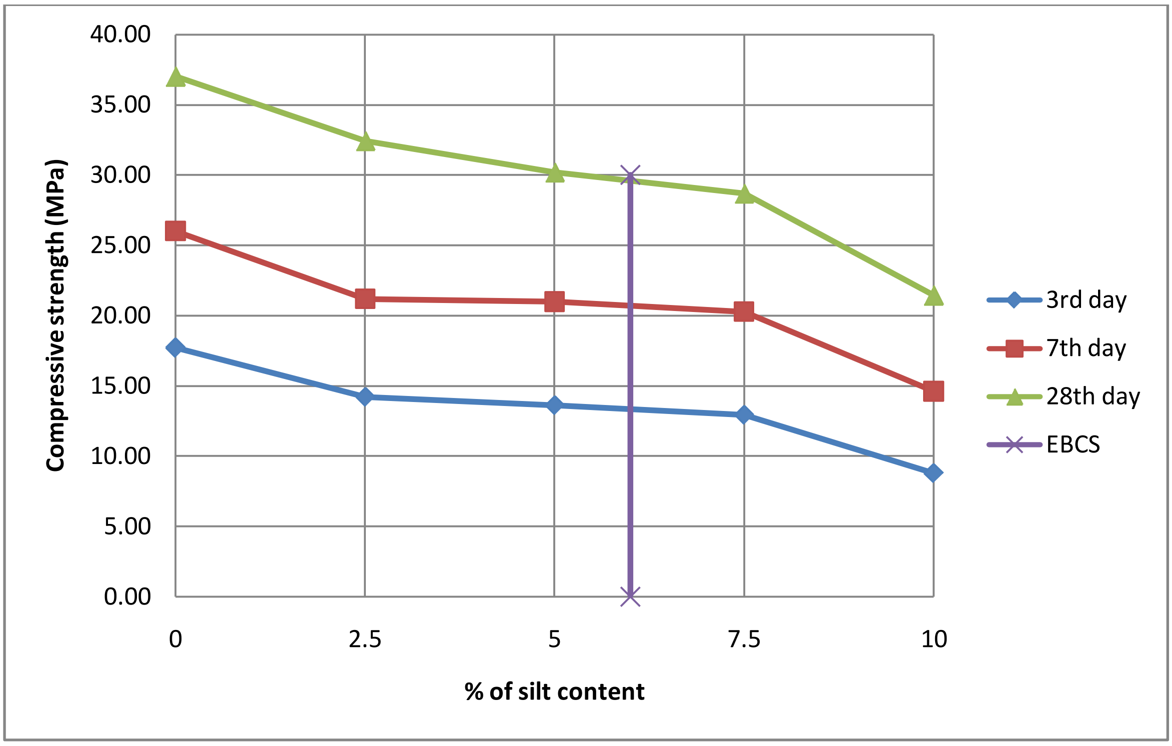


Figure 8: compressive strength versus % of silt content of sand

5.1.2 Results of test for tensile strength

Table 17: summary of applied load and Tensile strength test of concrete with percentage change of silt/clay content of sand

percentage of silt	sample	Load applied		tensile strength	
		7	**28**	**7**	**28**
0.00	1.00	172.60	194.00	2.44	2.75
	2.00	143.40	187.60	2.03	2.66
	3.00	_	189.50	_	2.68
	Average	**158.00**	**190.37**	**2.24**	**2.69**
2.50	1.00	109.20	145.20	1.55	2.06
	2.00	126.20	155.30	1.79	2.20
	3.00	_	126.70		1.79
	Average	**117.70**	**150.25**	**1.67**	**2.13**
5.00	1.00	92.50	144.30	1.31	2.04
	2.00	94.50	148.90	1.34	2.11
	3.00	_	141.00		2.00
	Average	**93.50**	**144.73**	**1.32**	**2.05**
7.50	1.00	86.70	119.50	1.23	1.69
	2.00	89.20	132.10	1.26	1.87
	3.00	_	88.60		1.25
	Average	**87.95**	**125.80**	**1.24**	**1.78**
10.00	1.00	81.90	96.50	1.16	1.37
	2.00	71.80	113.60	1.02	1.61
	3.00	_	113.70		1.61
	Average	**76.85**	**107.93**	1.09	**1.53**

Table 18: summary of average tensile strength of concrete with percentage change of silt/clay content of sand

Percentage of silt	Average tensile strength	
	curing time	
	7	**28**
0	2.24	2.69
2.5	1.67	2.13
5	1.32	2.05
7.5	1.24	1.78
10	1.09	1.53

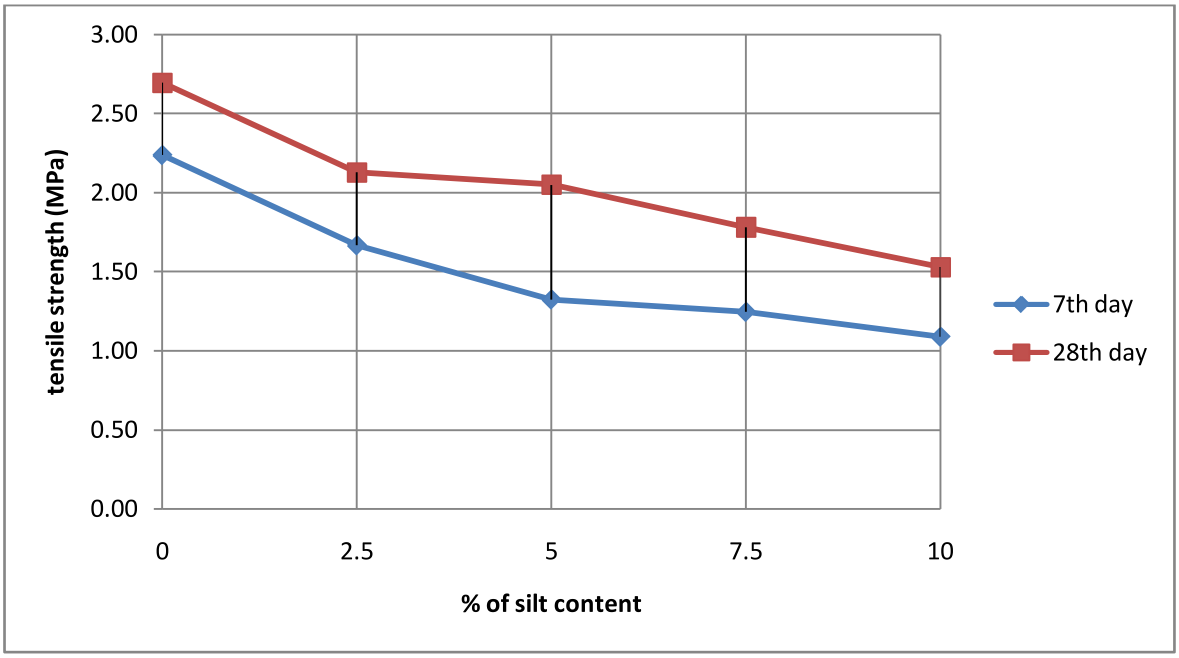


Figure 9: tensile strength versus % of silt content of sand

5.1.3 Test results of flexural strength of concrete

Table 19: summary of applied load and flexural strength of concrete with percentage change of silt/clay content of sand

percentage of silt	sample	Load applied	flexural strength
		28	**28**
0	1	7.20	4.43
	2	7.00	4.31
	Average	**7.100**	**4.37**
2.5	1	6.9	4.24
	2	6.7	4.12
	Average	**6.800**	**4.18**
5	1	6.60	4.06
	2	5.70	3.51
	Average	**6.150**	**3.78**
7.5	1	5.50	3.38
	2	5.60	3.44
	Average	**5.550**	**3.41**
10	1	4.8	2.95
	2	5.20	3.20
	Average	**5.000**	**3.08**

Table 20: summary of average flexural strength of concrete with percentage change of silt/clay content of sand

percentage of silt	average flexural strength at 28 day curing time
0	4.37
2.5	4.18
5	3.78
7.5	3.41
10	3.08

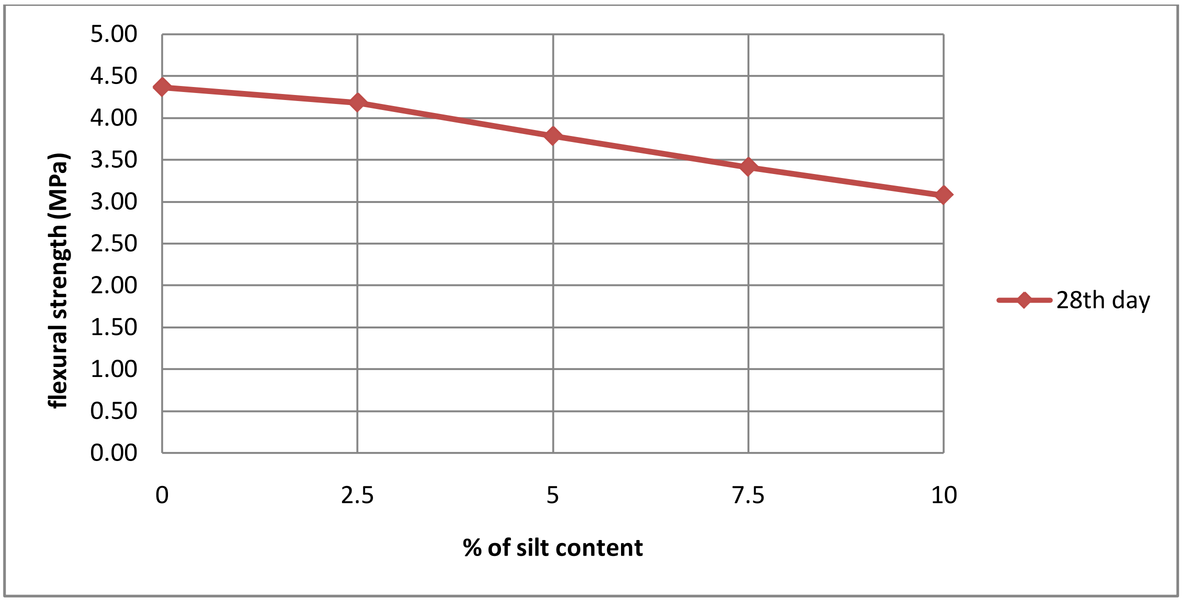


Figure 10: Flexural strength versus % of silt content of sand

5.2 Discussion

5.2.1 Compressive strength of concrete

As can be seen from table 16 and figure 6 above the compressive strength of concrete is decreased with the increase of clayey silt content of sand. In the curing times of 3, 7, and 28 days the percentage reduction of compressive strength of concrete as the clayey silt content of sand increases from 0 % to 10% is 50.18%, 43.82%, 42.07% respectively. In the 28 days curing time the magnitude of percentage reduction in compressive strength as the clayey silt content of sand increases from 7.5% to 10% (25.27%) is higher than the magnitude of percentage reduction from 0% to 2.5% (12.38%). Even though there is a reduction of compressive strength with the increase of clayey silt content of sand from 2.5% to 5% and from 5% to 7.5%, it is not as much as the percentage reduction from 0% to 2.5% and from 7.5% to 10% of clayey silt content of sand. From the figure of result above as the curing time increases, the percentage reduction of compressive strength of the concrete decreases which shows that clayey silt content of the sand affects hydration reaction.

As can be observed from the result of the test of compressive strength in figure 6 as the silt content varies from 2.5% to 7.5%, the compressive strength of concrete varies gradually and is almost within the range of the maximum silt content recommended by Ethiopian building Code standard (EBCS) which is 6%. It shows us that, up to 6% silt content of the sand alarmingly affect the strength of the concrete and the maximum limit of the silt content that is recommend by Ethiopian building Code standard (EBCS) can be used further in the actual construction practice of our country.

5.2.2 Tensile strength of concrete

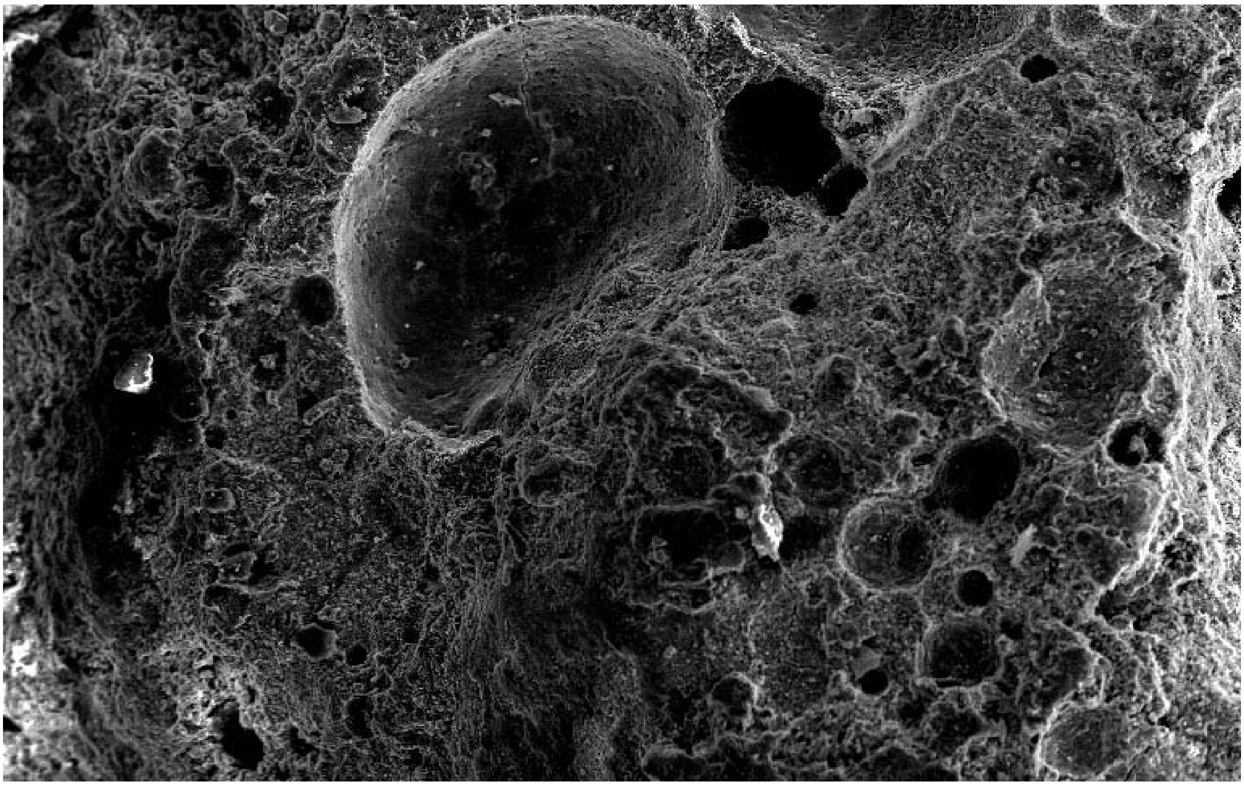
Values from table 18 or figure 7 above indicates that the tensile strength of concrete decreases with the percentage increase of clayey silt content of sand. For the curing times of 7 and 28 days, the percentage reduction of tensile strength of concrete as the clayey silt content of sand increases from 0 % to 10% is 51.36%, 43.3% respectively. In the 28 day curing time, the magnitude of percentage reduction in tensile strength as the clayey silt content of sand increases from 0% to 2.5% (21.07%) is higher than the magnitude of percentage reduction from 7.5% to 10% (14.2%). Even though there is a reduction of tensile strength with the increase of silt content of sand from 2.5% to 5% and from 5% to 7.5%, it is not as much as the percentage reduction from 0% to 2.5% and from 7.5% to 10% of clayey silt content of sand. From the figure of result above as the curing time increases, the percentage reduction of compressive strength of the concrete decreases which shows that clayey silt content of the sand affects hydration reaction.

5.2.3 Flexural strength of concrete

Obviously, one can observe the values from table 20 or figure 8 above that the flexural strength of concrete decreases with the percentage increase of clayey silt content of sand. . In the curing time of 28 days the percentage reduction of flexural strength of concrete as the clayey silt content of sand increases from 0 % to 10% is 29.58%. In the 28 day curing time the magnitude of percentage of reduction in flexural strength as the clayey silt content of sand increases from 7.5% to 10% (9.91%) is higher than the magnitude of percentage of reduction from 0% to 2.5% (4.23%). The percentage reduction of flexural strength of concrete is higher and in almost linear as the percentage clayey silt content of sand increases from 2.5% to 10% than the percentage reduction of flexural strength as the clayey silt content of sand increases from 0% to 2.5%.

Generally as the clayey silt content of sand increases from 0% to 10%, the percentage reduction of tensile strength (43.3) is almost the same as that of the reduction of compressive strength (42.07%), and the percentage reduction of compressive strength (42.07) and tensile strength (43.3) is greater than the reduction of flexural strength (29.58) of concrete in a 28 curing days. Therefore the tensile and compressive strength of concrete is highly affected as the clayey silt content of sand increases.

This reduction of strength of concrete due to the percentage increment of clayey silt content of sand is due to



a. 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.
b. The water absorbed in the silt does not contribute for hydration process.
c. As silt content increases, the bond between cement and aggregate particles reduces and the nature of interface between the aggregate and cement reduces, too.
d. At present, the mechanism through which clays influence the physical properties of cement paste has not been conclusively established. Depending on the nature of the swelling in these clays we can envision two different scenarios upon adding the cement powder to the mixture:
   1. 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. Decreasing in mixing water will reduce the workability of the concrete. This lack of water for hydration is therefore decreases the strength of the concrete.

2. The dispersed clay has the ability for macroscopic swelling. These particular types of clays, when placed in contact with water, experience an exfoliation of the stacked unit layers. 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 unhydrated 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 [4].

Therefore, it can clearly be seen that a significant amount of clayey silt in a cement mixture reduces the amount of water available for the hydration reactions and thereby decreases its workability and alters the course of the pozzolanic reactions. As a result, hardened cement containing clay minerals is expected to have different physical properties from that of cement fabricated without clays. It has been widely reported that presence of clays in cement reduces the compressive strength and increases shrinkage in the resulting concrete.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Hence, from the aforesaid discussion of results above, it can be seen that the higher the clayey silt content of sand the less compressive, tensile and flexural strengths and the more reduced workability of the concrete at a given water-cement ratio.

6.2 Limitations

This research is conducted using a a natural (river) sand from a particular place named as simbo river found in horu gudru east welega zone oromia region around fincha sugar factory and the result of the thesis work is restricted for that particular place only, but to be able to conclude that the strength of the concrete is reduced by a certain percentage as the percentage of clayey silt content increases, further research must be conducted using natural (river) sand from different sites of our country.

6.3 Recommendation

I. If the percentage of clay/silt content of the sand is more than 7.5%, then remedial measures such as washing of sand or cement increment should be taken so as to mitigate the effect of clayey silt content of the sand.

II. Mechanism should be set up, which will make intending contractors to indicate the areas where they intend to source for their sand. This will afford the consultant structural engineer to carry out appropriate test on the sand from such area and recommend means of mitigating the effect of the clay/silt content of such sand if necessary.

III. Producing excellent mix design in laboratory cannot guarantee for the quality of structures constructed on site. As a result, parties in the construction industry should strive hard and work very intimately so that laboratory tests should be carried out considering the prevailing site conditions and concrete materials handling on site must be done strictly in compliance with laboratory results and specifications so that the desired quality structure can be constructed.

IV. Research should be carried out on the possibility of producing a machine capable of washing sand locally.

6.4 Areas of further studies

1. Studies on the mitigation of clay content of sand on concrete strength
2. Cost analysis should be carried out between % increment of cement for sand with particular percentage silt/clay content so as to maintain a particular compressive strength, and the cost of washing the sand free of silt/clay, so as to determine which one out of the two is cost effective.
3. Studies should be carried out for longer and continuous moist curing, different curing conditions and longer term compressive strength test for further comparison among the concretes produced from different percentage of silt content.
4. Studies should be carried out on the Effects of fines modulus of sand on concrete strength

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ANNEX- I

Mix design

CONCRETE MIX DESIGN **FOR C-25** - **Trial No.#1**			
Specified Characteristic Strength by Cube:		**25 Mpa**	
Required Slump: **25-75 mm**	**Trademark of cement**	**Date:**	**27/05/2013**
Parameter	*Specification*	*Reference*	
Type of cement	*PPC (Derba)*		
Maximum Cement content	*≤ 550 kg/m^3*	ERA STS 8404 CLAUSE (d)	
Maximum Water/Cement Ratio	*0.5*	ERA STS 8404 CLAUSE (c)	
Water/Cement Ratio	*0.48*	ACI 211.1-81 table A1.5.3.4(a)	
Required Cube Compressive Strength in Mpa	*25*	ERA STS 8404-1	
Standard deviation in Mpa	*5*	ACI Table 2.8-1	
Design Cube Compressive Strength in Mpa	*30*		
The maximum nominal size of coarse aggregate in mm	*20*		
% Air for non-air entrained	*2.25%*	ACI 211.1-81 A1.5.3.3	
Slump required in mm			
Cement content in Kg/m^3	360		
Water in Kg/m^3	*172.8*		

	Specific Gravity	absorption%	volume (m^3)	Unit wt. (Kg/m^3)	Moisture Content%	%Proportion (Coarse & Fine aggregate)	%Proportion of Coarse aggregate(10-20mm & 5-10mm) to obtain the desired grading	Combined Specific Gravity of Coarse Aggregate
Cement	3.15	0	114.286	1400				
Aggregate 10-20mm	2.784	1.66		1439	0	**53**	**75**	**2.776**
Aggregate 5-10mm	2.753	2.40		1277	0	**18**	**25**	
Natural Sand	2.627	6.13		1365	0	**30**		
Air	1	0	22.500					
Water	**1**	**0**	172.8					
Total			**309.586**			**100.0**	**100**	

Volume of Sand & Coarse Aggregate =		690.414	For 1bag of cement (50 kg)					
Sand Proportion in mix %		30						
Sand to aggregate Ratio		0.429						
	Mass Kg/m^3	Volume m^3	Kg	Volume in m^3	Box size for 1 bag of Cement			
Aggregate (5-10mm & 10-20mm)	1319.292				**Length in m**	**Width in m**	**Height in m**	Height Ratio In terms of Cement
Aggregate 5-10mm	329.823	119.797	45.81	0.036	**0.50**	**0.40**	**0.18**	**1**
Aggregate 10-20mm	989.469	355.387	137.43	0.096	**0.50**	**0.40**	**0.48**	**3**
Natural Sand	565.411	215.230	78.53	0.058	**0.50**	**0.40**	**0.29**	**2**
Cement	360.0	114.286	50.00	0.036	**0.50**	**0.40**	**0.18**	1
Water	172.800	172.800	24.00					
Air		22.500						
Estimated Concrete Density	2417.503	1000.000						

Adjusted mass for the trial batch

Material	Trial Batch 9 Cubes + 5 cylinder +2 beam	Total volume **0.0738 m^3**
Aggregate (5-10mm & 10-20mm)	Individual mass in Kg for batch	
Aggregate 5-10mm	24.3	
Aggregate 10-20mm	73.0	
Natural Sand	41.7	
Cement	26.6	
Water	12.7	

ANNEX- I I

Results of cube compressive strength of concrete (raw data)

Date specimens were cast: 26/06/2013							
Description of test specimens: cube test							
Maximum size C.A. 20mm; F.M. 2.84; % of silt content. 0 %							
Spec. No.	Days cured	Weight	Area mm^2	Load KN	Stress MPA	% f'_c	date tested
A1	3	8.495	22500	397.8	17.68		6/29/2013
A2		8.490	22500	403.5	17.93		6/29/2013
A3		8.580	22500	394.1	17.52		6/29/2013
average		**8.522**	**22500**	**398.467**	**17.710**		
A4	7	8.565	22500	586.8	26.08		7/3/2013
A5		8.610	22500	597.1	26.54		7/3/2013
A6		8.570	22500	571.9	25.42		7/3/2013
average		**8.582**	22500	**585.267**	**26.012**		
A7	28	8.790	22500	732.1	32.54	rejected	7/24/2013
A8		8.570	22500	851.8	37.86		7/24/2013
A9		8.585	22500	813.8	36.17		7/24/2013
average			22500		**37.01**		

Date specimens were cast: 02/07/2013							
Description of test specimens: cube test							
Maximum size C.A. 20mm; F.M. 2.84; % of silt content. 2.5 %							
Spec. No.	Days cured	Weight	Area mm^2	Load KN	Stress Mpa	% f'_c	date tested
B1	3	8.452	22500	323.2	14.36		7/5/2013
B2		8.499	22500	318.2	14.14		7/5/2013
B3		8.483	22500	319.6	14.20		7/5/2013
average		**8.478**	22500	**320.333**	**14.237**		
B4	7	8.455	22500	478.1	21.25		7/9/2013
B5		8.421	22500	476	21.16		7/9/2013
B6		8.512	22500	475.7	21.14		7/9/2013
average		**8.463**		**476.600**	**21.182**		
B7	28	8.575	22500	719.9	32.00		7/30/2013
B8		8.46	22500	734	32.62		7/30/2013
B9		8.51	22500	735.1	32.67		7/30/2013
average		**8.515**		**729.667**	**32.430**		

Date specimens were cast: 29/06/2013							
Description of test specimens: cube test							
Maximum size C.A. 20mm; F.M. 2.84; % of silt content. 5 %							
Spec. No.	Days cured	Weight	Area mm^2	Load KN	Stress Mpa	% f'_c	date tested
C1	3	8.486	22500	310.3	13.79		7/2/2013
C2		8.539	22500	307.5	13.67		7/2/2013
C3		8.504	22500	301.6	13.40		7/2/2013
average		**8.510**	22500	**306.467**	**13.62**		
C4	7	8.318	22500	487.3	21.66		7/6/2013
C5		8.426	22500	470.7	20.92		7/6/2013
C6		8.467	22500	458.4	20.37		7/6/2013
average		**8.404**	22500	**472.133**	**20.984**		
C7	28	8.51	22500	669.1	29.74		7/27/2013
C8		8.41	22500	695.1	30.89		7/27/2013
C9		8.45	22500	673.7	29.94		7/27/2013
average		**8.46**	22500	**679.30**	**30.19**		

Date specimens were cast: 01/07/2013							
Description of test specimens: cube test							
Maximum size C.A. 20mm; F.M. 2.84; % of silt content. 7.5 %							
Spec. No.	Days cured	Weight	Area mm^2	Load KN	Stress Mpa	% f'_c	date tested
D1	3	8.42	22500	305.6	13.58		7/4/2013
D2		8.445	22500	272.5	12.11		7/4/2013
D3		8.435	22500	297	13.20		7/4/2013
average		**8.433**	22500	**291.700**	**12.964**		
D4	7	8.438	22500	460.1	20.45		7/8/2013
D5		8.47	22500	463.8	20.61		7/8/2013
D6		8.512	22500	445.3	19.79		7/8/2013
average		**8.473**	22500	**456.400**	**20.284**		
D7	28	8.566	22500	649.7	28.88		7/29/2013
D8		8.647	22500	651.5	28.96		7/29/2013
D9		8.596	22500	635.3	28.24		7/29/2013
average			22500	**645.50**	**28.69**		

Date specimens were cast: 28/06/2013							
Description of test specimens: cube test							
Maximum size C.A. 20mm; F.M. 2.84; % of silt content. 10 %							
Spec. No.	Days cured	Weight	Area mm^2	Load KN	Stress Mpa	% f'_c	date tested
E1	3	9.056	22500	238.5	10.60		7/1/2013
E2		8.246	22500	198.8	8.84		7/2/2013
E3		8.907	22500	198.2	8.81		7/3/2013
average		**8.736**	22500	**211.833**	**8.822**		
E4	7	8.17	22500	326.6	14.52		7/5/2013
E5		8.305	22500	327.3	14.55		7/5/2013
E6		8.349	22500	332.5	14.78		7/5/2013
average		**8.275**	22500	**328.800**	**14.613**		
E7	28	8.432	22500	472.6	21.00		7/26/2013
E8		8.315	22500	487	21.64		7/26/2013
E9		8.295	22500	487.6	21.67		7/26/2013
average		**8.347**		**482.4**	**21.44**		

ANNEX- III

Results of direct tensile strength of concrete (raw data)

Date specimens were cast:26/06/2013						silt= 0%	
Description of test specimens: Same concrete mix design as for specimens tested in compression							
Average diameter measured at the middle of specimen-15cm							
Spec. No.	Days cured	Area mm^2	Load KN	Tensile Stress kPa	% f'_c.	date tested	remark
A1	7		172.6	2.44		7/3/2013	
A2			143.4	2.03		7/3/2013	
average			**158**	**2.24**			
A3	28		194	2.75		7/24/2013	
A4			187.6	2.66		7/24/2013	
A5			189.5	2.68		7/24/2013	
average			**190.37**	**2.69**			

Date specimens were cast: 02/07/2013						silt= 2.50%	
Description of test specimens: Same concrete mix design as for specimens tested in compression							
Average diameter measured at the middle of specimen-15cm							
Spec. No.	Days cured	Area mm^2	Load KN	Tensile Stress kPa	% f'_c	date tested	remark
B1	7		109.2	1.55			7/9/2013
B2			126.2	1.79			7/9/2013
average			**117.7**	**1.67**			
B3	28		145.2	2.06			7/30/2013
B4			155.3	2.20			7/30/2013
B5			126.7	1.79			7/30/2013
average			**142.4**	**2.02**			

Date specimens were cast: 29/06/2013						silt= 5%	
Description of test specimens: Same concrete mix design as for specimens tested in compression							
Average diameter measured at the middle of specimen-15cm							
Spec. No.	Days cured	Area mm^2	Load KN	Tensile Stress kPa	% f'_c	date tested	remark
C1	7		92.5	1.31		7/6/2013	
C2			94.5	1.34		7/6/2013	
average			**93.5**	**1.32**			
C3	28		144.3	2.04		7/27/2013	
C4			148.9	2.11		7/27/2013	
C5			141	2.00		7/27/2013	

Date specimens were cast: 01/07/2013						silt= 7.50%	
Description of test specimens: Same concrete mix design as for specimens tested in compression							
Average diameter measured at the middle of specimen-15cm							
Spec. No.	Days cured	Area mm^2	Load KN	Tensile Stress kPa	% f'_c	date tested	remark
D1	7		86.7	1.23		7/8/2013	
D2			89.2	1.26		7/8/2013	
average			**87.95**	**1.24**			
D3	28		119.5	1.69		7/29/2013	
D4			132.1	1.87		7/29/2013	
D5			88.6	1.25		7/29/2013	
average			**113.4**	**1.61**			

Date specimens were cast: 28/06/2013						silt= 10%	
Description of test specimens: Same concrete mix design as for specimens tested in compression							
Average diameter measured at the middle of specimen-15cm							
Spec. No.	Days cured	Area mm^2	Load KN	Tensile Stress kPa	% f'_c	date tested	remark
E1	7		81.9	1.16		7/5/2013	
E2			71.8	1.02		7/5/2013	
average			**76.85**	**1.09**			
E3	28		96.5	1.37		7/26/2013	
E4			113.6	1.61		7/26/2013	
E5			113.7	1.61		7/27/2013	
average			**107.93**	**1.53**			

ANNEX- I V

Results of flexural strength of concrete (raw data)

Date specimens were cast :26/06/2013						silt= 0%	
Description of test specimens : 10cm*10cm*51cm beams; Distance between supports -							
Spec. No.	Days cured	Area mm^2	Load KN	location of Fracture	M.R Mpa	% f'_c	date tested
A1	28		7.2	19	4.43		7/24/2013
A2			7	21	4.31		7/24/2013
average			7.1	20	4.37		

Date specimens were cast : 02/07/2013						silt= 2.50%	
Description of test specimens : 10cm*10cm*51cm beams; Distance between supports -							
Spec. No.	Days cured	Area ($mm^{2)}$ (b*d)	Load KN	location of Fracture	M.R Mpa	% f'_c	date tested
B1	28		6.9		4.24		7/30/2013
B2			6.7		4.12		7/30/2013
average			**6.8**		**4.18**		

Date specimens were cast : 29/06/2013						silt= 5%	
Description of test specimens : 10cm*10cm*51cm beams; Distance between supports -							
Spec. No.	Days cured	Area mm^2 (b*d)	Load KN	location of Fracture	M.R Mpa	% f'_c	date tested
C1	28		6.6		4.06		7/27/2013
C2			5.7		3.51		7/27/2013
average			6.15		3.78		

Date specimens were cast : 01/07/2013						silt= 7.50%	
Description of test specimens : 10cm*10cm*51cm beams; Distance between supports -							
Spec. No.	Days cured	Area mm^2	Load KN	location of Fracture	M.R Mpa	% f'_c	date tested
D1	28		5.5		3.38		7/29/2013
D2			5.6		3.44		7/29/2013
average			5.55		3.41		

Date specimens were cast : 28/06/2013						silt= 10%	
Description of test specimens : 10cm*10cm*51cm beams; Distance between supports -							
Spec. No.	Days cured	Area mm^2 (b*d)	Load KN	location of Fracture	M.R Mpa	% f'_c	date tested
E1	28	10000	4.8	18	2.95		7/26/2013
E2		10000	5.2	21	3.20		7/26/2013
average			5		3.08		