Jimma University

School of Graduate Studies

Jimma Institute of Technology

Faculty of Civil and Environmental Engineering

Construction Engineering and Management Chair

INFLUENCE OF RIVER SAND MOISTURE CONTENT ON FRESH AND HARDENED CONCRETE PROPERTIES

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

BY: SHIMELIS METABU

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February, 2020
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Advisor: Engr. Bien Maunahan

Co-Advisor: Engr. Moges Getahun

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DECLARATION

I declare that this research report entitled "Influence of river sand moisture content on fresh and hardened concrete properties" is original work of my own, has not been presented for a degree of MSc by other researchers in any other university and that all sources of material used for the thesis have been duly acknowledged.

Mr. Shimelis Matebu

______________________________ ________________________________

Signature Date

As masters research advisors, we here by certify that we have read and evaluate this MSc research prepared under our guidance, by Mr. Shimelis Matebu entitled: "Influence of river sand moisture content on fresh and hardened concrete property.

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

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ABSTRACT

The fresh and hardened concrete properties are affected by water-cement ratio and the extensive way of water addition in the concrete is from aggregates. Aggregates contain some moisture based on the porosity of the particles and the moisture condition of the storage area. Fine aggregate can contain up to 10% of surface moisture content which causes significant variation in the mixing water content. Therefore the main objective of the study was to study the influence of river sand moisture content on fresh and hardened concrete properties.

In the research work, river sand quarried from Gambella and brought Jimma for selling was preferred as it is the commonly used sand in Jimma. Before using the sand in concrete, the physical property tests were conducted to identify as the sand meets the requirements of the standards. The concrete was then mixed varying the moisture contents of the sand from 1% to 10% in steps of 1%. The properties of concrete including workability, unit weight, compressive strength, and split tensile strength were conducted and compared with control and the standard specifications.

The results of the Gambella river sand sample material properties test showed a meeting of Ethiopian and ASTM standard specifications. The workability of the concrete showed reduction as the moisture contents of the sand increased. However, the slumps of sand up to 3% moisture contents resulted within 25-50mm. The unit weight of the concrete showed a slight reduction as the sand moisture content increased. But, all the densities of the concrete mix exceeded the 1850kg/m^3 which is the maximum density required for lightweight aggregate concrete. Compressive and tensile strengths decreased as the moisture contents of river sand moisture content increased. However, the influence of the moisture contents of river sand was not significant on tensile strength compared to the compressive strength. Meanwhile, the river sand having moisture content up of 9%, 6% and 4% satisfied ACI 209 criteria at 7th, 14th and 28th curing days respectively. Therefore, the moisture contents of the river sand should be considered during mixing the concrete on site and kept constant.

Key words: Concrete, Moisture Content, Compressive Strength, River Sand, tensile Strength.

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ACRONOMYS

AASHTO	American Association State Highway and Transportation Officials
ACI	American Concrete Institute
AD	Air Dry
ASTM	American Society for Testing and Materials
BS	British Standard
EBCS	Ethiopian Building Code Standards
ES	Ethiopian Standard
F.M.	Fineness Modulus
Gs	Specific gravity
IS	Indian Standard
JU	Jimma University
Kg	Kilo Gram
MC	Moisture content
mm	Millimeter
MPa	Mega Pascal
NO.	Number
OD	Oven-dry
OPC	Ordinary Portland Cement
PPC	Portland Pozzolana Cement
RCA	Recycled-Concrete-Aggregate
SSD	Saturated Surface Dry
T	Ton
Wt.	Weigh

CHAPTER ONE

INTRODUCTION

1.1. Background

Concrete is the world's most consumed man-made material, basically composed of two components: paste and aggregate. The paste contains cement and water and sometimes other cementitious and chemical admixtures, whereas the aggregate contains sand and gravel or crushed stone. The paste binds the aggregates together, and the aggregates are relatively inert filler materials [54].

The aggregates make up about 60 to 80 percent of the total volume and 70 to 85 percent of the total weight of concrete; its quality is of considerable importance. Aggregate is classified into two different types, coarse and fine. Coarse aggregate is usually greater than 4.75 mm (retained on a No. 4 sieve), while fine aggregate is less than 4.75 mm (passing the No. 4 sieve) [4].

Fine aggregates generally consist of natural sand or crushed stone with most particles smaller than 5mm. Natural gravel and sand are usually dug or dredged from a pit, river, lake, or seabed. Crushed stone is produced by crushing quarry rock, boulders, cobbles, or large-size gravel. Crushed air-cooled blast-furnace slag is also used as a fine or coarse aggregate [5].

The fresh and hardened concrete specimen properties are affected by the water-cement ratio [30, 48]. The moisture content of an aggregate is an essential factor when developing the proper water/cementitious material ratio. All aggregates contain some moisture based on the porosity of the particles and the moisture condition of the storage area. The moisture content can range from less than one percent in gravel to up to 40 percent in very porous sandstone and expanded shale.

A design water-cement ratio is usually specified based on the assumption that aggregate are inert (neither absorb nor give water to the mixture) but in most cases aggregate from different sources do not comply with this, i.e. wet aggregate give water to the mix, and drier aggregate (those with below-saturated level moisture content) take water from the mix affecting, in both cases, the design water-cement ratio and therefore workability and strength of the mix. To correct for these discrepancies, the moisture content of aggregates has to be determined [63].

Aggregate can be found in four different moisture states that include oven-dry (OD), air-dry (AD), saturated-surface dry (SSD), and wet. Of these four states, only OD and SSD correspond to a specific moisture state and can be used as reference states for calculating moisture content. In order to calculate the quantity of water that aggregate will either add or subtract to the paste, the following three quantities must be calculated: absorption capacity, effective absorption, and surface moisture [39].

Water content is the most important factor affecting the workability of concrete. Increasing the amount of water will increase the workability of concrete also result in segregation and bleeding [19]. The change in workability with time depends on the moisture condition of aggregate, evaporation and hydration reaction. The loss of workability is greater with dry aggregate due to the absorption of water by aggregate. [22].

The moisture content in concrete has a significant effect on concrete strength. Moisture content in the concrete decrease the compressive strength and pressure tensile strength, but have a much lesser effect on the splitting tensile strength. Oven drying increases the compressive strength and splitting tensile strength, but decreases the pressure tensile strength sharply [29, 30].

The w/c (or w/cm) ratio of concrete has major influence on the permeability of concrete. As the w/c ratio decreases the porosity of the paste decrease and the concrete becomes more impermeable. This variation of permeability with w/c ratio is largely due to large capillary porosity rather than gel pores [20]. This property of concrete plays a great role in the durability of the concrete because it controls the entry of moistures which may contain aggressive chemicals and the movement of water during heating and freezing.

River sand is a widely used construction material in Ethiopia, especially in the production of concrete and cement-sand mortar [12]. Therefore, this research attempts to study the influence of natural river sand moisture content on fresh and hardened concrete properties.

1.2. Statement of the problem

The fundamental requirement for making concrete structures is to produce good quality concrete. Good quality concrete is produced by carefully mixing cement, water, and fine and coarse aggregate and combining admixtures as needed to obtain the optimum product in quality [18]. For a given cement and acceptable aggregates, the strength that may be developed by a workable, properly placed mixture of cement, aggregate, and water (under the same mixing, curing, and testing conditions) is mainly influenced by ratio of cement to mixing water [37].

However, in construction site, water is often added for easy concrete placing and concrete passing between steel spacing. The added water can help easy workability and finishability but concrete with added water shows segregation of aggregates and degradation of performance both in strength and durability [25]. In the concrete with the same unit cement content, hydration can be more activated with larger unit water content. But the consumed water for hydration reaction in cement paste develops to more pores which lead to reduction of strength and resistance to deterioration even in the same hydrate product amount. Porosity is also considered as durability index [13].

There are many ways of addition of extra water in the concrete mix, which cause change in the designed specification of concrete. The extensive way of water addition in the concrete is from aggregates. The aggregate moisture causes significant variation in the mixing water content. If the aggregates are stored in the outdoor environment then rain and sun exposure can cause water variation [51]. Coarse aggregate rarely contains more than 1% of surface moisture but fine aggregate can contain in excess of 10% [41].

Water content has been cited by many researchers as one of the variables that affect the properties of a concrete. However, nothing has been done to study the influence of the sand moisture content on fresh and hardened concrete properties. Therefore this thesis deals with studying the influence of river sand moisture content variation on fresh and hardened concrete properties.

1.3. Research question

1) What are some engineering properties of selected river sand?
2) What are the influences of river sand moisture content levels on fresh and hardened properties of concrete?
3) At which moisture content level river sand concrete test results comply with Standards and Specifications?

1.4. Objective

1.4.1. General Objective

The main objective of this research work was to study the influence of river sand moisture content on fresh and hardened concrete properties.

1.4.2. Specific Objectives

The specific objectives of the study are:

1) To identify some engineering properties of selected river sand
2) To investigate fresh and hardened properties of concrete at different river sand moisture contents
3) To compare test results with Standards and Specifications.

1.5. Significance of the Study

Results obtained from this study provided lessons that could help the concerned body to come up with appropriate measures to address problems resulting from using river sand containing different moisture contents on the strength and performance of concrete. The study also provides other researchers to use these findings as a reference for further research on related areas.

1.6. Scope of the Study

This study was focused on studying the influence of river sand moisture content on fresh and hardened concrete properties. Using such different level of river sand moisture content can influence the physical and mechanical properties of concrete. Therefore the original scope of this study was to study the influence of river sand different moisture content levels on fresh and hardened concrete properties and comparing with control concrete. And comparing test results with Standards and Specifications to identify the suitable moisture content level that could be used in concrete successfully.

1.7. Limitations of the Study

In this study, chemical composition and organic content of river sand and long term strength and durability property of concrete were not tested due to time and laboratory equipment constraints. The allocated budget for this research was also not sufficient enough to take sample from more than one river sources.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

Concrete is a composite material produced by the homogenous mixing of selected proportions of water, cement, and aggregates (fine and coarse). Strength is the most desired quality of a good concrete. It should be strong enough, at hardened state, to resist the various stresses to which it would be subjected [4].

This chapter is, therefore, dedicated in discussing about Constitutes of concrete, fresh and hardened concrete property, influence of river sand moisture content on fresh and hardened concrete properties.

2.2. Constitutes of Concrete

This section summarizes the properties of all the components used in the various concrete mixes. Concrete is a structural material that contains some simple elements but when mixed with water would form a rock like material. Concrete mix is comprised of coarse aggregates usually gravel, fine aggregates usually sand, cement, water, and any necessary additives. Concrete possesses many favorable properties as a structural material, among which are its high compressive strength and its property as a fire-resistant element to a considerable extent.

The unfavorable properties include a relatively weak tensile strength as compared to its compressive strength and the ability to form cracks in unpredictable areas. With steel bars as internal reinforcement, the cracks can be controlled to some degree. Unlike other building materials such as steel and plastic, concrete is not a uniform material due to the fact that it contains a ratio of gravel and sand, thus failure mode or location of the failure is unpredictable [52].

Due the nature of concrete, concrete has an ability to have its recipe changed or altered to meet situational needs. Thus, if a job calls for high strength, lightweight or weather resistant concrete, its recipe is available or a custom one can be devised. Concrete has three main components when it's freshly mixed and they are water, cement and aggregates. Water is needed to begin the hydration process for the concrete and after four weeks of curing until full potential strength of the concrete can be achieved [52].

2.2.1. Cement

Cement is a hydraulic binder and is defined as a finely ground inorganic material which, when mixed with water, forms a paste which sets and hardens by means of hydration reactions and processes which, after hardening, retains its strength and stability even under water [11].

The history of making cementing material is as old as the history of engineering construction. Some kind of cementing materials were used by Egyptians, Romans and Indians in their ancient constructions. The early Greeks and Romans used cementing materials obtained by burning limestone. The remarkable hardness of the mortar used in early Roman brickworks, some of which still exist, presents sufficient evidence of the perfection which the art of cementing material had attained in ancient times [11].

The world's annual production of cement, was around 4.2 billion tons in 2016 [44]. In Ethiopia, the first cement factory was established by Italians in 1936. The plant had an initial capacity of 120 tonnes of clinker per day [59] Currently the country has more than 16 cement plants having installed production capacity of 17.15 million tons in 2016 [36].

2.2.1.1. Types of cement

There are different types of cement depending on their composition, method of manufacturing (grinding, burning, etc.) and also the relative proportion of the different compounds. One of these types and the most commonly used one is Portland cement, which in turn is divided into many types. The other common type of cement is Portland pozzolana cement which contains some amount of pozzolanic materials.

2.2.1.1.1. Portland cement

The origin of the name "Portland cement" is usually attributed to Joseph Aspdin, a brick mason in England who in 1824 took out a patent for making a powder made from mixed and ground hard limestone and finely divided clay. This forms into slurry and then is calcined in a furnace till the CO_2 was expelled. He called the resulting material Portland cement because when the mortar made with it hardened it produced a material resembling the stone which was quarried near Portland, England [32]. The method of making cement has been improved upon since that time but the basic process has remained the same.

The Portland cement is the chief ingredient in cement paste and the binding agent in Portland cement concrete. It is a hydraulic cement that, when combined with water, hardens into a solid mass. Interspersed in an aggregate matrix it forms Portland cement concrete. According to Hakan Avsar Portland cement has been used for well over 185 years and, from an empirical perspective, its behavior is well understood [10].

It is one of the most widely used cement. It is used in mortar, in all types of structural concrete like walls, floors, bridges, tunnels, etc. It is further used in all types of masonry works like foundations, footings, dams, retaining walls, and pavements. When Portland cement is mixed with sand and lime, it serves as mortar for laying brick and stone; and when it is mixed with coarse aggregate and fine aggregate (sand) together with enough water, to ensure a good consistency, we get concrete [20].

Eight types of Portland cement are covered in ASTM C 150 standard. These types and descriptions of their uses are listed in Table 2.1 [9].

Table 2.1: Portland cement types and their uses as ASTM C 150 [9].

Cement Type	**Uses**
TypeI	General purpose cement, when there are no extenuating conditions
TypeII	Aids in providing moderate resistance to sulfate attack
TypeIII	When high-early strength is required
TypeIV	When a low heat of hydration is desired
TypeV	When high sulfate resistance is required
TypeIA	A type I cement containing an integral air-entraining agent
TypeIIA	A type II cement containing an integral air-entraining agent
TypeIIIA	A type III cement containing an integral air-entraining agent

The composition of Portland cement distinguishes one type of cement from another. The phase compositions in Portland cement are denoted as tricalcium silicate (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3A), and tetracalcium aluminoferrite (C_4AF) as in the Table 2.2.

Table 2.2: Main constituents in a typical Portland cement [42].

Chemical Name	**Chemical Formula**	**Shorthand Notation**	**Percent by Weight**
Tricalcium Silicate	$3CaOSiO_2$	C_3S	54.1
Dicalcium Silicate	$2CaOSiO_2$	C_2S	16.6
Tricalcium Aluminate	$3CaOAl_2O_3$	C_3A	10.8
Tetracalcium Aluminoferrite	$4CaOAl_2O_3Fe_2O_3$	C_4AF	9.1
Minor compounds	-	-	-

The actual components are often complex chemical crystalline and amorphous structures, denoted by cement chemists as "alite" (C_3S), "belite" (C_2S), and various forms ofaluminates. The behavior of each type of cement depends on the content of these components [61].

Tricalcium silicate (C_3S) hydrates and hardens rapidly and is largely responsible for initial set and early strength. Portland cements with higher percentages of C_3S will exhibit higher early strength[2]. Dicalcium silicate (C_2S) hydrates and hardens slowly and is largely responsible for strength increases beyond one week [11].

Tricalcium aluminate (C_3A) hydrates and hardens the quickest. It liberates a large amount of heat almost immediately and contributes somewhat to early strength. Gypsum is added to Portland cement to retard C_3A hydration. Without gypsum, C_3A hydration would cause Portland cement to set almost immediately after adding water [11].

Tetracalcium aluminoferrite (C_4AF) hydrates rapidly but contributes very little to strength. Its presence allows lower kiln temperatures in Portland cement manufacturing. Most Portland cement color effects are due to C_4AF. [11].

2.2.1.1.2. Portland Pozzolana cement

PPC is manufactured by the intergrinding of OPC clinker with 15 to 35% of pozzolanic materials [33]. Pozzolanic materials are siliceous or aluminous materials which by themselves possess little or no cementitious properties. But in the presence of water they react with calcium hydroxide which is liberated from the hydration of cement to form a compound possessing cementitious property.

The reaction of the pozzolanic materials with calcium hydroxide results in many advantages of PPC over OPC. If these pozzolanic materials were not reacted with the calcium hydroxide, free calcium hydroxide would have been present in the concrete resulting in higher permeability of the concrete and susceptibility to other attacks. The pozzolanic reaction reduces the porosity of the concrete by producing cementitious compound. It also reduces the heat of hydration since its reaction is slower than that of OPC, which implies that it has slower rate of strength than OPC, making it suitable for mass concrete construction.

In addition to these cement types there are also other types of cement which are produced by either adding other materials to the clinker or by forming other compounds during burning. They are collectively called modified Portland cements. Expansive cement, calcium sulfoaluminate cement, masonry cement, oil well cement, white cement etc. can be an example for this. There are also non-Portland inorganic cements which are used to some extent.

2.2.2. Water

Water is one of the most important elements in concrete production. Water is needed to begin the hydration process by reacting with the cement to produce concrete. There has to be a sufficient amount of water available so that the reaction can take its full course but if too much water is added, this will in fact decrease the strength of the concrete. The water-cement ratio is an important concept because other than the recipe for the concrete mix, the amount of water used would also determine its finial strength [45].

In more details, if too little water were added, there would not be enough water available to finish the reaction, thus some of the cement would harden and bond with other dry cement shorting the hydration process. On the other hand, if too much water were added then while the cement is undergoing hydration the cement would be in a slurry solution, and the probability of cement bonding with aggregates would decrease. And as a result, when the hydration process is completed, the cement content would still be in a slurry solution and with no strength.

The type of water that can be used to mix concrete must be potable which is essentially has neither noticeable taste nor odor. Basically, water containing less than 2000 ppm of total dissolved solids can be used. Thus the type of water that was used to mix concrete throughout the testing program was normal tap water with attention paid for not including impurities.

2.2.3. Aggregates

Aggregate is granular material such as sand, gravel, crushed stone, blast-furnace slag, and lightweight aggregates that usually occupies approximately 60 to 75% of the volume of concrete. Aggregate properties significantly affect the workability of plastic concrete and also the durability, strength, thermal properties, and density of hardened concrete [57]. The quality of aggregate is considerably important because at least three-quarters of the volume of concrete is occupied by it [40]. 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 among other things to three important requirements [19].

I). Workability, when fresh for which the size and gradation of the aggregate should be such that undue labor in mixing and placing will not be required.

2). Strength and durability when hardened for which the aggregate should be: be stronger than the required concrete strength, contain no impurities which adversely affect strength and durability, Not go in to undesirable reaction with the cement and be resistant to weathering action

3). Economy of the mixture –meaning to say that the aggregate should be: Available from local and easily accessible deposit or quarry, well graded in order to minimize paste hence cement requirement.

2.2.3.1. Aggregates Properties

2.2.3.1.1. Grading

Grading refers to the distribution of particle sizes present in an aggregate. The grading is determined in accordance with ASTM C 136, "Sieve or Screen Analysis of Fine and Coarse Aggregates." A sample of the aggregate is shaken through a series of wire-cloth sieves with square openings, nested one above the other in order of size, with the sieve having the largest openings on top, the one having the smallest openings at the bottom, and a pan underneath to catch material passing the finest sieve [57].

That portion of an aggregate passing the 4.75 mm (No. 4) sieve and predominantly retained on the 75 µm (No. 200) sieve is called "fine aggregate" or "sand," and larger aggregate is called "coarse aggregate" [57].

Gradation plays an important role in the workability, segregation, and pump ability of the concrete. Grading changes are more prevalent than shape and surface texture in the case of coarse aggregates. For example, uniformly distributed aggregates require less paste which will also decrease bleeding, creep and shrinkage while producing better workability, more durable concrete and higher packing. A graded aggregate, as opposed to a single-size aggregate, will have a greater packing density [47]. The volume of the voids between roughly spherical aggregate particles is greatest, when the particles are of uniform size. When a range of sizes is used, the smaller particles can pack between the larger there by decreasing the void space and lowering paste requirement. Using a larger maximum aggregate size can also reduce the void space [55].

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. In general, aggregates that do not have a large deficiency or excess of any size and give a smooth grading curve will produce the most satisfactory results [27].

2.2.3.1.2. Fine-Aggregate Grading and Fineness Modulus

The most desirable fine-aggregate grading depends on the type of work, the richness 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 [27].

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 [53].

Formerly two classes of fine aggregate were recognized but it has been shown that by adjusting the ratio of the fine to coarse aggregate a good concrete could be obtained with either classes of aggregate. In 1954 the revision to BS 882 considers four grading zones. In BS 882:1973 the division into zones is based primarily on the percentage passing the 600µm sieve .The main reason for this is that a large number of sands divide themselves naturally at just that size, grading above and below being approximately uniform. Furthermore, the content of particles finer than the 600µm sieve has considerable influence on the workability of the mix and provides a fairly reliable index of the overall specific surface of the sand [40]. Table 2.3 shows the grading requirement of British standard and ASTM for fine aggregate. BS 882 divides the grading in to four zones, zone 1 is coarser and zone 4 is finer. Grading zone 2 and 3 is optimum grading zones and approach to ASTM standard. Since the British standard is wider than ASTM standard, the local fine aggregate may fit to one of the zones and it is better to adapt to Ethiopian standards.

Table 2.3: BS and ASTM grading requirement for fine aggregate [40].

sieve size	Percentage by weight passing sieves					
	BS 882:1973					ASTM standard C33-78
BS	ASTM NO	Grading Zone 1	Grading Zone 2	Grading Zone 3	Grading Zone 4	
9.5mm	3/4in	100	100	100	100	100
4.75mm	3/16in	90-100	90-100	90-100	95-100	95-100
2.36mm	8	60-95	75-100	85-100	95-100	80-100
1.18mm	16	30-70	55-90	75-100	90-100	50-85
600µm	30	15-34	35-59	60-79	80-100	25-60
300µm	50	5-20	8-30	12-40	15-50	10-30
150µm	100	0-10	0-10	0-10	0-15	2-10

Sand falling in to any of the above zone can generally be used in concrete although under some circumstances the suitability of a given sand my depend on the grading and shape of coarse aggregate Subjected value of coarse to fine aggregate ratio is given in Table 2.4 as follows [40].

Table 2.4: Suggested proportion by weight of coarse to fine aggregate for sand of different zone

Maximum size of coarse aggregate		**Coarse /fine aggregate ratio for sand of different zones**			
mm	in	Zone 1	Zone 2	Zone 3	Zone 4
9.52	3/8	1	1.5	2	3
19.05	3/4	1.5	2	3	3.5
38.1	1.5	2	3	3.5	-

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.

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 the aggregate size, the higher the FM. For fine aggregate used in concrete, the FM generally ranges from 2.3 to 3.1 as called for in ASTM C33 [57].

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 [3].

Fine sand: F.M. 2.2 - 2.6

Medium Sand: F.M. 2.6 - 2.9

Coarse Sand: F.M. 2.9 - 3.2

Sand having a fineness modulus more than 3.2 will be unsuitable for making satisfactory concrete [3]. 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 [40].

2.2.3.1.3. Coarse-Aggregate Grading

The coarse aggregate grading requirements of ASTM C 33 (AASHTO M 80) permit a wide range in grading and a variety of grading sizes. The grading for a given maximum-size coarse aggregate can be varied over a moderate range without appreciable effect on cement and water requirement of a mixture if the proportion of fine aggregate to total aggregate produces concrete of good workability. [7].

Mixture proportions should be changed to produce workable concrete if wide variations occur in the coarse-aggregate grading. Since variations are difficult to anticipate, it is often more economical to maintain uniformity in manufacturing and handling coarse aggregate than to reduce variations in gradation. The maximum size of coarse aggregate used in concrete has a bearing on the economy of concrete. Usually more water and cement is required for small-size aggregates than for large sizes, due to an increase in total aggregate surface area [27].

2.2.3.1.2. Bulk Density

The bulk density or unit weight of an aggregate is the mass or weight of the aggregate required to fill a container of a specified unit volume. The volume referred to here is that occupied by both aggregates and the voids between aggregate particles [27]. The bulk density is used to convert quantities by weight to quantities by volume for batching concrete. Bulk specific gravity determined on the saturated surface-dry basis is used if the aggregate is wet, that is, if its absorption has been satisfied. Conversely, the bulk specific gravity determined on the oven-dry basis is used for computations when the aggregate is dry or assumed to be dry (ASTMC128) [7].

Bulk density depends on the moisture content of the aggregate. For coarse aggregate, increasing moisture content increases the bulk density; for fine aggregate, however, increasing moisture content beyond the saturated surface-dry condition can decrease the bulk density. This is because thin films of water on the sand particles cause them to stick together so that they are not as easily compacted. The resulting increase in volume decreases the bulk density.

Other properties that affect the bulk density of an aggregate include grading, specific gravity, surface texture, shape, and angularity of particles. Angularity increases void content while larger sizes of well-graded aggregate and improved grading decreases void content. The rodded bulk density of aggregates used for normal weight concrete generally ranges from 1200 to 1760 kg/m^3 [57].

2.2.3.1.3. Specific Gravity

The density of the aggregate is required in mix proportioning to establish weight volume relationships. The density is expressed as the specific gravity, which is a dimensionless ratio relating the density of the aggregate to that of water [55].

$$SG = \frac{Density\ of\ sold}{Density\ of\ water} \qquad \text{(Eq. 2.1)}$$

Because the aggregate mass varies with its moisture content, specific gravity is determined at fixed moisture content. Four moisture conditions are defined for aggregates depending on the amount of water held in the pores or on the surface of the particles [57].

1. Damp or wet-Aggregate in which the pores connected to the surface are filled with water and with free water also on the surface.

2. Saturated surface-dry-Aggregate in which the pores connected to the surface are filled with water but with no free water on the surface.

3. Air-dry-Aggregate that has a dry surface but contains some water in the pores.

4. Oven-dry-Aggregate that contains no water in the pores or on the surface.

The bulk specific gravity is defined as the ratio of the weight in air of a given volume of a material at the standard temperature to the weight in air of equal volume of distilled water at the standard temperature. For use in the computation of concrete mixes the bulk specific gravity is always determined for saturated surface dry aggregates [3]. Most natural aggregates have relative densities between 2.4 and 2.9 with corresponding particle (mass) densities of 2400 and 2900 kg/m3 [27].

2.2.3.1.4. Silt Content

Sand which is a product of natural or artificial disintegration of rocks and minerals is obtained from glacial, river, lake, marine, residual and wind-blown deposits. These deposits however do not only provide sand but also 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 materials 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. Therefore it is necessary that one make a test on the silt content and checks against permissible limits.

A simple test which can be made on site to give a guide to the amount of silt in natural sand is the field settling test. This test is based on the fact that large heavy particle will settle rapidly in water while small light particle will settle most slowly. This test is only fit for normal sand and should not be used for crushed rock sands.

The British and American standards (BS 882, ASTM C-33) limit the clay and silt content not to be more than 3% of the total weight of the fine aggregate. Unlike these standard limits the Ethiopian standard gives more allowance by about 3% more. According to the Ethiopian standard it is recommended to wash the sand or reject it if the silt content exceeds a value of 6 % [1].

2.2.3.1.5. Absorption and Surface Moisture

2.2.3.1.5.1. Mixing Water and Water-Cementitious Material Ratio

The various moisture states in which an aggregate may exist have been described previously. Two of these oven-dry and saturated surface-dry are used as the basis for calculations of specific gravity. Aggregates stockpiled on the job are seldom in either of these states. They usually carry some free or surface moisture that becomes part of the mixing water. Freshly washed coarse aggregates contain free water, but because they dry quickly, they are sometimes in an air-dry state when used, and they absorb some of the mixing water [57].

The mixing water in a batch of concrete is all the water present in the concrete, with the exception of absorbed water within aggregate particles. Mixing water is the sum of the masses of free or surface moisture on the fine and coarse aggregate and the mass of water added separately, such as through a water meter or weigh batcher at the plant or through a truck mixer water system or added to the mixer in some other way. Mixing water is the water in freshly mixed sand-cement grout, mortar, or concrete exclusive of any previously absorbed by the aggregate [57]. The w/cm is the mass ratio of mixing water to cementitious material.

2.2.3.1.5.2. Absorption and Total Moisture Content

To calculate the mixing water content of concrete, the absorption of the aggregates and their total moisture contents must be known. Absorption represents the total water contained in the aggregate in the saturated surface-dry condition and the surface moisture (or free moisture) is the water in excess at the saturated surface-dry state.

The total water content of a damp or moist aggregate is equal to the sum of absorption and surface moisture content. It should be noted that if the aggregates are dry they absorb water from the mixing water and there by affect the workability and, on the other hand, if the aggregates contain surface moisture they contribute extra water to the mix and thereby increase the water/cement ratio. Both these conditions are harmful for the quality of concrete. In making quality concrete, it is very essential that corrective measures should be taken both for absorption and free moisture so that the water/cement ratio is kept as exactly as per the mix design [3].

Absorption is computed as a percentage by subtracting the oven-dry mass from the saturated surface-dry mass, dividing by the oven-dry mass, and multiplying by 100. In concrete technology, aggregate moisture is expressed as a percent of the dry weight of the aggregate [57].

$$\text{Absorption } \% = \frac{WSSD-WOD}{WOD}*100 \qquad \text{(Eq. 2.2)}$$

2.2.3.2. Fine aggregate overview

Sand is the second most widely used commodity on earth after water. Almost 80 percent of the construction industry is made up of sand. The booming construction industry, real estates, the buildings in which majority of government offices are, etc., all are constructed with the help of sand [64].

Sand is the principal component of concrete, the critical construction material and deserves special attention when considering the means of process control. Unlike coarse aggregate where various types of crushers may be used to upgrade mineral quality, sand basically relies on the same techniques to address both mineral quality and sizing [28].

Moreover, sand is a key component of inland and coastal eco-systems. Unselective mining of sand degrades rivers beds, Make Rivers change course, and degrades the fishery base. Sand helps maintain groundwater tables and keeps saline water from intruding into freshwater sources in coastal areas. Beach sand is our natural defense against rising sea-levels [28].

As naturally existing material sand may not exist in a pure state i.e. some very fine particles such as dust, silt and clay may intrude in it. In order to remove the necessary amounts of these fines most sands are produced with wash water and water classification. The key to all rinsing and water classifying systems is adequate delivery of water. Inadequate water supply and poor maintenance are the two most common reasons for inconsistent sand gradations [28].

2.2.3.3. Sources of fine aggregates

Generally, sand is found on the banks of rivers and beaches of seas or oceans. The rivers carry sediments with them and due to erosion in the due course of motion rounding of boulders happens from which small fragments are released from the parent rock and the process continues with the newly formed fragments along with boulders. Thus, minute particles finally suspend and are carried along with the river flow which is generally termed as sand. Whenever we are mining the sand from these areas, there is always a “replenishment capacity per year” associated with every river or bank in a particular area. If sand is mined within this limit, then it is environmentally sustainable- else, disasters are prone to happen [14].

It is generally accepted that sand and gravel are widely distributed and abundant near existing and past rivers and streams, in alluvial basins, and in previously glaciated areas. Regardless of the wide distribution, these aggregates are not universally available for use. Where the locality lacks the aggregate source, the costly alternatives of importing aggregate from outside the area or substituting another material for aggregate is considered.

Basically, the sources of natural fine aggregate are of three types [64].

2.2.3.3.1. River sand

The River sands are obtained, as the name implies, from banks or beds of rivers. River sand has the property of being fine and consists of fine rounded grains. The color of river sand is almost white and grayish. River sand is usually available in clean condition and is used for plastering [64].

2.2.3.3.2. Pit sand (Coarse sand)

This type of sand is procured from deep pits of abundant supply. It has a property of being coarse grained which is sharp, angular and free from salts. It mostly has a reddish yellow color and mostly employed in concreting [64].

2.2.3.3.3. Sea/Marine sand

As the name implies, sea sand is taken from sea shores. It has fine rounded grains and it is light brown in color. Sea sand is avoided for the purpose of constructing concrete structure since it contains salt and tends to absorb moisture from the atmosphere and brings dampness [64].

2.4. Fresh concrete properties

Concrete plays a vital role in the development of infrastructure, buildings, industrial structures, bridges and highways etc. leading to utilization of large quantity of concrete. It is difficult to point out another material of construction which is as vital as concrete. Where strength, durability, impermeability and fire resistance are required, concrete is the best material [58].

2.4.1. Workability of Concrete

ASTM C 125 defines workability as the property determining the effort required to manipulate freshly mixed quantity of concrete with minimum loss of homogeneity. The term "manipulate" includes the early age operations of placing, compacting and finishing [6].

A workable concrete allows full compaction using a reasonable amount of work. This helps in achieving maximum possible density (i.e. minimum possible voids) of concrete, which results in more strength and durability of concrete [41].

Water content is the most important factor affecting the workability of concrete. Increasing the amount of water will increase the workability of concrete. However the increase in water content of the mix will decrease the strength and also result in segregation and bleeding [19].

The amount of aggregate, the proportion and fine aggregate and shape and texture of the aggregate particles affect the workability of concrete. Keeping the water content and cement content constant increasing the amount of aggregate reduces the workability of concrete [19].

Freshly mixed concrete stiffens with time. The change in workability with time depends on the moisture condition of aggregate, evaporation and hydration reaction. The loss of workability is greater with dry aggregate due to the absorption of water by aggregate. The workability of a concrete is also affected by the temperature of the concrete itself [41].

2.5. Hardened concrete properties

Generally, the term concrete strength is taken to refer to the uniaxial compressive strength as measured by a compression test of a standard test cylinder or cube, because this test is used to monitor the concrete strength for quality control or acceptance purposes. For convenience, other strength parameters, such as tensile or bond strength, are expressed relative to the compressive strength [31].

2.5.1. Compressive Strength

Concrete is required to provide a specified strength. The most common measure of concrete strength is the compressive strength, determined either using a cube or a cylinder. Although in many practical cases other characteristics, such as durability and permeability may in fact be important [2].

The compressive strength of concrete attracts greatest interest as compared to other types of concrete strengths since compressive strength of concrete is mostly used for designing of building structures. In addition, it has a great practical and economic significance because the sections and sizes of the concrete structures are determined by it [56].

Since most concrete structures are designed to resist compressive stress, it is this property which is usually prescribed by codes or standards. The strength of concrete depends on the cohesion of the cement paste, on its adhesion to the aggregate particles, and to a certain extent on the strength of the aggregate itself [41].

The compressive strength of concrete is dependent on many things. The hydration reaction, water to Cement ratio, aggregate type, amount and size, water content, cement content, curing condition, cement type, compaction method used etc. have an effect on the strength of concrete. Strength at any W/C ratio depends on the degree of hydration of the cement and its physical and chemical properties. The decrease in the water content of the concrete results in a higher strength of the concrete. The water required for the hydration reaction is less than that of the mixing water; the extra water provided is used to make the concrete more workable [20].

The compaction of the fresh concrete reduces the amount of entrapped air and therefore increases the strength of the concrete. It is found that for each 1 % of air entrapped there will be a 5 to 6 % loss on strength. Curing temperature affects the hydration of cement and hence the duration of strength gains. Cubes kept at about 10_oC will have their 7 day strength reduced by 30% and their 28 day strength by 15% [1].

2.5.2. Tensile Strength of Concrete

The tensile strength of concrete falls between 8 and 15 percent of the compressive strength. The actual value is strongly affected by the type of test carried out to determine the tensile strength, the type of aggregate, the compressive strength of the concrete, and the presence of a compressive stress transverse to the tensile stress [31].

Standard Tension Tests

Two types of tests are widely used. The first of these is the modulus of rupture or flexural **test** (ASTM C78), in which a plain concrete beam, generally long, is loaded in flexure at the third points of a 24-in. span until it fails due to cracking on the tension face [8]. The flexural tensile strength or modulus of rupture, from a modulus-of-rupture test is calculated from Eq. 2.3, assuming a linear distribution of stress and strain:

$$Fr = \frac{6M}{bh^2} \qquad \text{(Eq.2.3.)}$$

Where,

M = moment

h = overall depth of specimen

b = width of specimen

The second common tensile test is the split cylinder test (ASTM C496), in which a standard compression test cylinder is placed on its side and loaded in compression along a diameter. In a split-cylinder test, an element on the vertical diameter of the specimen is stressed in biaxial tension and compression. The stresses acting across the vertical diameter range from high transverse compressions at the top and bottom to a nearly uniform tension across the rest of the diameter [43]. The splitting tensile strength, f_{ct}, from a split cylinder test is computed with Eq. 2.4 as shown below:

$$f_{ct} = \frac{2P}{\pi l d} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (Eq. 2.4.)$$

where:

P = maximum applied load in the test

L = length of specimen

d = diameter of specimen

The tensile strength of concrete is affected by the same factors that affect the compressive strength. In addition, the tensile strength of concrete made from crushed rock may be up to 20 percent greater than that from rounded gravels. The tensile strength of concrete made from lightweight aggregate tends to be less than that for normal sand-and-gravel concrete, although this varies widely, depending on the properties of the particular aggregate under consideration [15, 60].

The tensile strength of concrete develops more quickly than the compressive strength. As a result, such things as shear strength and bond strength, which are strongly affected by the tensile strength of concrete, tend to develop more quickly than the compressive strength. At the same time, however, the tensile strength increases more slowly than would be suggested by the square root of the compressive strength at the age in question [15].

2.5.3. Age of Concrete

The strength of concrete increases appreciably with age, and hydration of cement continues for months. In practice the strength of concrete is determined from cylinders or cubes tested at the age of 7 days and 28 days. As a practical assumption concrete at 28 days is 1.5 times as strong as at 7 days. The range varies b/n 1.3 and 1.7. The British Code of Practice accepts concrete if the strength at 7 days is not less than two thirds of the required 28 days strength. For a normal Portland cement, the increase of strength with time, relative to 28 days strength, may be assumed as on Table 2.5 :[21].

Table 2.5: Concrete strength with age [21].

Age	7 days	14 days	28 days	3 months	6 months	1 year	2 years	5 years
Strength ratio	0.67	0.86	1	1.17	1.23	1.27	1.31	1.35

2.5.4. Durability of Concrete

The durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack and abrasion while maintaining its desired engineering properties. Different concretes require different degrees of durability depending on the exposure environment condition. The concrete ingredients, proportioning of those ingredients, interactions between the ingredients, and placing and curing practices determine the durability and life of the concrete [38].

The durability of concrete depends mostly upon conditions of exposure, grade of concrete used, quality of its materials and the extent of voids and pores present in the concrete cover over the reinforcement also influences the durability of concrete [66].

The durability of concrete is a function of permeability. Hence concrete can be made durable by reducing the extent of voids by suitable grading and proportioning the materials, using adequate quantity of cement and low water cement ratio thereby ensuring impermeability [41].

2.5.5. Permeability of concrete

The movement of fluid through a porous medium due to a pressure head difference is called permeability. Thus ability of the concrete to transmit fluids through it caused by pressure head difference is called permeability of concrete. This term applies to both gases and liquids. This property of concrete plays a great role in the durability of the concrete because it controls the entry of moistures which may contain aggressive chemicals and the movement of water during heating and freezing. Durability of concrete refers to the ability of concrete to resist weathering actions, chemical attacks, abrasions or any processes of deteriorations.

The w/c (or w/cm) ratio of concrete has major influence on the permeability of concrete. As the w/c ratio decreases the porosity of the paste decrease and the concrete becomes more impermeable. This variation of permeability with w/c ratio is largely due to large capillary porosity rather than gel pores. Tests to measure permeability usually fall into three categories [55]. Two of them involve the movement of water through concrete, while the third one involves the movement of electric charge.

2.6. Influence of moisture content on fresh concrete property

The properties of fresh concrete are extremely important. Consistency and workability of fresh concrete are significant criteria for the concrete mix design proportioning and important properties affecting the placing of fresh concrete on site and the later performance of the hardened state of concrete. Workability represents diverse characteristics of freshly mixed concrete that are difficult to measure quantitatively. Workability involves certain characteristics of fresh concrete such as cohesiveness and consistency. Cohesiveness (stability) is a measure of the compactibility and finish ability of fresh concrete.[34].

Concrete workability increase as moisture content of concrete increase. Higher the water content per cubic meter of concrete, the higher will be the fluidity of concrete, which is one of the important factors affecting workability. Adding more water to concrete has disadvantages as; increased quantity of water may cause bleeding in concrete, Cement slurry also escapes through the joints of formwork and Strength of concrete may reduce [26].

2.7. Influence of moisture content on hardened concrete property

[30] Series of tests designed for the research were performed encompassing two water/cement ratios (0.45 and 0.65) and various moisture contents. In order to induce different moisture contents, specimens were subjected to 28 days of standard moist curing and 28 days of ambient curing, followed by complete immersion for varying periods prior to testing.

Analysis of the collected data suggests that the moisture content in concrete has a significant effect on concrete strength. Moisture content in the concrete will decrease the compressive strength and pressure tensile strength, but have a much lesser effect on the splitting tensile strength. Oven drying increases the compressive strength and splitting tensile strength, but decreases the pressure tensile strength sharply. By comparing the data from the splitting tensile test to that from the pressure tensile test, it was also established that the latter test procedure possesses great potential for certain specialized applications. For example, oven drying of concrete generates significant damage within the concrete microstructure, which has a significant effect on the mechanical properties and failure mechanisms exhibited by the pressure tension test, as compared to the splitting tension test.

The experimental results obtained by Ross et al. [50, 65] also reveal that both the compressive strength and tensile strength of concrete decreased somewhat with any increasing moisture content at a low loading rate.

Moisture content in concrete does have a significant effect on the compressive strength of concrete, but have much lesser effect on the split tensile strength. As the specimen degrees of saturation increased, the compressive strength fell. However, at early saturated condition, increase in compressive strength can be found [16].

[25] For OPC mortar with constant cement content and additional water content, various durability tests are performed. The conclusions on effect of W/C ratio on durability and porosity in cement mortar with constant cement amount are as follows. Cement mortar with constant W/C ratio of 0.45 and air amount 5.2% is prepared and its durability performances are quantitatively investigated with adding mixing water to 0.60 of W/C ratio. The increasing W/C ratio causes increasing porosity to 150% compared with control case (W/C 0.45). With increasing porosity, interesting patterns with porosity are evaluated, which are linear relationships (W/C ratio, compressive strength, and chloride diffusion coefficient), square root of porosity (water loss and air permeability), and square of porosity (sorptivity and moisture diffusion coefficient) with high determinant coefficient over 0.9.

With increasing water content from 0.45 to 0.60 of w/c (133% increase), it is evaluated that the increase ratios are 139% in water loss, 150% in porosity, 157% in chloride diffusion coefficient, 192% in air permeability, 259%in moisture sorptivity, and 266% in moisture diffusion coefficient. In the compressive strength, it decreases to 75.6% for control case (W/C 0.45).

2.8. Influence of aggregates/river sand moisture content on fresh concrete property

Poon et al. [46] used natural and coarse RCA with different moisture conditions to prepare concrete. The effects of moisture condition of the aggregates on the properties of fresh concrete were investigated. It was found that the slump of fresh concrete was affected by the moisture condition. Dry aggregates led to a higher initial slump and quicker slump loss, while wet aggregates had normal initial slumps and slump losses. The initial slump of concrete was strongly dependent on the initial free water content of the concrete mixes.

According to Barra and Vazquez [17], the poor result of concretes with saturated and dry recycled aggregates and the good result of those made from semi-saturated aggregates can be explained as being caused by formation of a more solid and denser interface in this condition.

1. Due to water absorption by recycled aggregates, moisture conditioning of coarse recycled aggregates is needed in order to maintain the right workability. The RCA used in pre-wetting and saturated-surface-dry conditions improve the concrete workability.

2. The obtained results showed that the kinetics of water absorption by recycled aggregates is fast in the early minutes when aggregates are in contact with water. The workability loss, in terms of slump loss appears to decrease after 30 min.

2.9. Influence of aggregates/ river sand moisture content on hardened concrete property

Several reported works have studied the influence of water absorption by recycled aggregates on properties of concrete. Barra de Oliveira and Vazquez [17, 35] were the first who discussed the influence of retained moisture of recycled aggregate on the properties of hardened concrete. They observed a slight decrease in the strength of the concrete made from dry and saturated recycled aggregates. This decrease is especially noticeable in flexural strength in the concrete of saturated recycled aggregates. They also noted that the resistance to the freeze-thaw test is shown to be particularly sensitive for detecting differences in concretes with different levels of moisture retention in aggregates.

[35] Three series of concrete mixes were prepared and each series contain six mixes, where the RCA were used at rates of 0%, 20%, 40%, 60%, 80% and 100% of coarse aggregates total volume. RCA were used in three different moisture conditions: dry, pre-wetted and saturated-surface-dry (SSD), while natural aggregates were maintained in dry state for all concretes mixes.

Overall, the effect of moisture conditioning recycled aggregates on the compressive strength does not seem obvious. By comparing the results obtained of compressive strength according to recycled aggregates state, those used in the dry state have the best strength. The moisture conditioning of recycled aggregates (in states pre wetted and saturated surface-dried) seemed to have a negative effect on the strength development of the concrete, particularly for mixes prepared with replacement rates greater than 60% recycled aggregates. The use of recycled aggregates in the saturated-surface dry (SSD) state is not preferred. The loss of compressive strength of the concrete prepared with the recycled aggregates humidified until a SSD state may be attributed to the bleeding of concrete,

The tensile strengths of the concrete mixes at the age of 7^{th} and 28^{th} days show similar trend with the compressive strength, except for the drop in the strength which is smaller than the ratios between tensile strength to compressive strength which are ranging from 7 to 10%. It represents the perfect homogeneity of the concrete mixes. Similar to the results obtained in compressive strength, the recycled aggregates used in the dry state give the best strength. It should be noted that the tensile strength for all concrete mixtures at 28 days is well above the characteristic of tensile strengths according the European standard NF EN 206-1 for a desired compressive strength of 25 MPa.

The compressive strength of mixes concrete is not strictly linked to that of the splitting tensile strength. The correlation coefficients (R^2) are 0.08, 0.32 and 0.47 respectively at dry, pre-wetting and saturated-surface-dry (SSD) condition. These correlation coefficients (R^2) obtained from regression analysis indicate that the correlations between compressive strength and splitting strength were poor and are not significant to predict a strength from another defined strength.

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1. Methodology

3.1.1. Study area

Samples were collected from Jimma area which is located in south-western in the Oromia Region. It is one of the most populated towns in Oromia National Regional State. It is located at $7^0$13'N – $8^0$56'N Latitude and $35^0$49' E – $38^0$38' E Longitude. It is about 335 km away from Addis Ababa in southwest direction. Jimma has a total estimated area of 19,506.24, which has been subdivided into 11 urban kebele (least administrative structure) administrations. The town is found in an area of average altitude, of about 5400ft (1780m) above sea level. It lies in the climatic zone locally known as Woina Degā which is considered ideal for agriculture as well as human settlement.

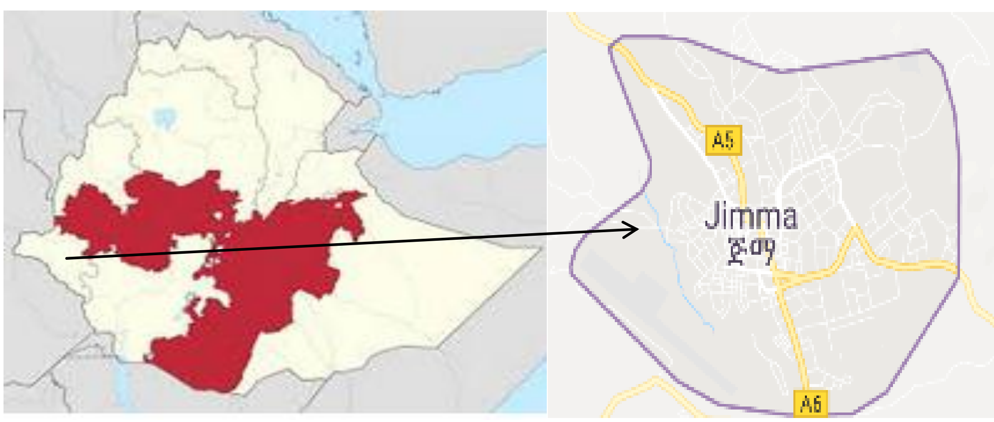

Figure 3.1: Location points of sampling area

3.1.2. Study variables

3.1.2.1. Dependent Variable

Fresh and hardened Properties of concrete by using different river sand moisture content level.

3.1.2.2. Independent variable

The variable which considered as independent variables are the moisture content level of the sand, Strength properties and qualities of concrete ingredients as coarse aggregate, fine aggregate (sand) and water used for mixing and curing the concrete specimens.

3.1.3. Dissemination plan

This research mainly concentrates for academic purposes that are enrolled by the Jimma University. The findings were presented to Jimma University, School of Graduate Studies, Jimma Institute of Technology, school of civil and environmental engineering, Construction Engineering and Management Chair. And disseminated to Jimma University library, all concerned government and nongovernment office. The research will be published on an international peer review journal in near future.

3.2. Material preparation

3.2.1. Cement

In this research, the locally produced cements, Dangote OPC of 42.5 grades was used for the preparation of the concrete specimens.

The Dangote OPC cement used in this research was tested for fineness by Sieve method using standard size sieve 90 µm (no.9) sieve). The degree of fineness of cement is measure of the mean size of grains in the cement. The fineness was tested by taking 100 gm of cement and sieving on a standard 90micron IS. sieve for 15 minutes and weighing residue left after 15 minutes of sieving. The percentage of residue weight was then calculated by dividing the weight of sample retained on the sieve to total weight of the sample i.e. 100 gm.

Normal consistency tests - The normal consistency of hydraulic cement refers to the amount of water required to make a neat paste of satisfactory workability. It is determined using Vicat apparatus. This apparatus measures the resistance of the paste to the penetration of a plunger or needle of 300 gm related at the surface of the paste.

The amount of water required for normal consistence is then expressed as a percentage by weight of the dry cement. Thus the usual range of water-cement ratio for normal consistency is b/n 26% and 33%.

Cement used in this study was Dangote OPC cement bought from the market and then its normal consistency and setting time was laboratory studied. In the research work, the researcher was carried out normal consistency and setting time cement tests.

Generally there are two types of setting time to determine in the laboratory, initial and final setting times. The initial setting time is the duration of cement paste related to 25 mm penetration of the Vicat needle in to the paste in 30 seconds after it is released while the final setting time is that related to zero penetration of the Vicat needle in to the paste.

3.2.2. Fine aggregate

Aggregates passing through a No 4 (4.75 mm) sieve and predominantly retained on a No. 200 (75 µm) sieve are classified as fine aggregate. The fine aggregate used in the concrete productions is river sand quarried from Gambella, which is about 427 km south-west of Jimma and brought Jimma for selling was preferred. In order to investigate its properties for the required application different tests were carried out which include: silt content, sieve analysis and fineness modules, specific gravity and absorption capacity, moisture content and unit weight.

3.2.2.1. Silt content

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

ASTM C 33 Limits deleterious (material finer than a 75 µm sieve) substances in fine aggregate to 5%. The Ethiopian standard restricts the silt content to a maximum of 6%. If it exceeds this maximum value the standard recommends washing or rejecting the sand.

3.2.2.2. Sieve analysis and Fineness Modules

Sieve analysis is a procedure used for the determination of the particle size distribution of the aggregate. It is also used to determine the fineness modulus, an index to the fineness, coarseness and uniformity of aggregates. These properties of the aggregate greatly affect the property of the concrete. The fine aggregate sieve analysis was conducted as per the grading requirement of ASTM C 33 standard as shown on Table 3.1.

Table 3.1: Sieve analysis requirements of the fine aggregate as per ASTM

Sieve size(mm)	**ASTM C 33 Limit (%)**	
	Lower limit	**Upper limit**
9.5	100	100
4.75	95	100
2.36	80	100
1.18	50	85
600mic	25	60
300mic	5	30
150mic	0	10
pan	-	-
Total	-	-

3.2.2.3. Specific gravity and absorption capacity

Specific gravity is an expression of the density of an aggregate. It is the ratio between the weight of the substance and that of the same volume of water. Aggregates contain pores in their structure, therefore the specific gravity depends on whether the pores are included in the measurement or not. Apparent specific gravity of an aggregate refers to the solid materials excluding the pores and bulk specific gravity refers to total volume i.e. including pores of the aggregate. The specific gravity and absorption tests of the river sand are performed according to ASTM C 128.

3.2.2.4. Moisture content

The water to cement ratio of a concrete affects the strength and the workability of the concrete. The increase of the water to cement ratio results in a decrease of the strength of the concrete and an increase of workability. The aggregates in concrete are assumed to be inert materials. But most of the aggregates don’t meet this assumption by either absorbing water (dry aggregates) or by releasing it (wet aggregates) to the mix. As a result of this property of aggregates, the design of water to cement ratio of the mix changes. Therefore it is important to determine both the absorption capacity and the moisture content of the aggregate.

The moisture content of fine aggregates was determined by oven drying 500gm of sample of fine aggregate in an oven at a temperature of 110^0c for 24 hrs. and dividing the weight difference by the oven dry weight.

3.2.2.5. Unit weight

Unit weight can be defined as the weight of a given volume of graded aggregate. It is thus a density measurement and is also known as bulk density. But this alternative term is similar to bulk specific gravity, which is quite a different quantity, and perhaps is not a good choice. The unit weight effectively measures the volume that the graded aggregate will occupy in concrete and includes both the solid aggregate particles and the voids between them.

The unit weight was simply measured by filling a container of known volume and weighing it. Then, dividing the aggregate weight by the volume of the container provided the unit weight of the fine aggregate.

3.2.3. Coarse aggregate

By the time the coarse aggregate is looked in the market to buy, there was no coarse aggregate which satisfy the required maximum aggregate size of 20 mm in the market. However, it was possible to obtain coarse aggregate satisfying the required size from Varnero Construction P.L.C.’s crushed stone manufacture site with the kind assistance. The aggregate have been stored in the laboratory for weeks and the visual examination reveals that there is a dust film on their surface and therefore, the aggregate was washed thoroughly and dried in open air state before any test was carried out. After washing and drying, the coarse aggregates were sieved and stored. This has minimized segregation and thus variation in gradation from mix to mix. The coarse aggregates used are with maximum aggregate sizes of 20 mm.

In order to investigate its properties different tests which include sieve analysis and fineness modules, specific gravity and absorption capacity, moisture content and unit weight were carried out.

3.2.3.1. Sieve analysis

The coarse aggregate used sieve analysis test was conducted as per ASTM 33-11 and the corresponding gradation curve along with the recommendations of the ASTM 33 - 11 shown on Table 3.2.

Table 3.2: Sieve analysis test recommendation of ASTM33 standard for coarse aggregate

Sieve size (mm)	**Percent passing (ASTM 33)**	
	Lower limit	Upper limit
25	100	100
19	90	100
9.5	20	55
4.75	0	10
2.36	0	5

3.2.3.2. Unit weight, specific gravity, moisture content and absorption capacity

Like that of the fine aggregate, all these laboratory tests were carried out in similar manner to identify the physical properties of the coarse aggregate and the test results were used to prepare mix design of the C-25 concrete following ACI standard.

3.2.4. Water

In this research, potable water supplied by Jimma Town Municipality found in the Jimma University, Jimma Institute of Technology was used for washing aggregates, concrete mixing and curing the concrete specimens.

3.3. Experimental Program on concrete

This experimental program consists of preparing different concrete mixes with different river sand moisture contents in order to study the performance of the concrete such as its unit weight, workability, compressive strength and tensile strength. To meet these objectives the following tasks were implemented.

3.3.1. Mix design of concrete

ACI method of mix design for C-25 class concrete was used throughout the laboratory program of this research with varying the moisture contents of river sand as shown on Table 3.3. The moisture contents of the sand were varied from 1% to 10% in steps of 1% by adding the water to the sand prior to proportioning and mixing in concrete. To get these different moisture contents of the sand, the quantity of water used was determined as it is summarized in Table 3.3.

Table 3.3: Water used to get the different moisture contents of sand to get 1m³ of Concrete used.

N0.	Mix Design	Fine Aggregate(kg/m^3)	Water(kg/m^3)
1.	MC1	806.00	8.06
2.	MC2	806.00	16.12
3.	MC3	806.00	24.18
4.	MC4	806.00	32.24
5.	MC5	806.00	40.30
6.	MC6	806.00	48.36
7.	MC7	806.00	56.42
8.	MC8	806.00	64.48
9.	MC9	806.00	72.54
10.	MC10	806.00	80.60

The concrete mixes were designed with a water cement ratios of 0.50 and cement contents of 370 kg/m^3. The steps showing concrete mix design using ACI methods are attached at the Annex B. The design mix proportions for 1 m^3 of the different C-25 concretes are as shown in the Table 3.4 by weight with their ratios. Therefore the concrete specimens were casted with 1: 2.17: 2.77

ratio and the water cement ratio of 0.5 was used for control concrete, while the moisture content of the fine aggregate were varied from 1% to 10%.

Table 3.4: Estimated batch weights per m^3 of concrete

N0.	Ingredient	weight	Ratio
1.	cement	370 kg	1
2.	Fine aggregate	806kg	2.17
3.	coarse aggregate	1026 kg	2.77
4.	water	184 kg	0.50
	Total	**2378kg**	

3.3.2. Concrete Production Process

The concrete molds and a slump cone were cleaned from all dust and coated with releasing agent (oil) to smooth the surface and to prevent sticking of mixed concrete with the mold and the cone. The preparation of the ingredient materials such as; cement, fine aggregate, coarse aggregate and water were made by using weight measurement. After all the ingredients weighed and prepared, fine aggregate, coarse aggregate and cement were added to mixer and mixed dry. Then the water was added to the dry mixed concrete ingredients mixture and mixed thoroughly as shown in Figure 3.2.

Immediately after mixing the concrete, 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 3.4.

Figure 3.2: Mixing the concrete ingredients.

3.3.3. Casting Concrete specimens

After the slump test was checked, the fresh concrete was then poured in to the molds and 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. After that the top surface is finished using a trowel. Cubes having 150 mm x 150 mm x 150 mm size and cylinder having 100 mm diameter and 200 mm height was casted to check compressive strength and tensile strength respectively.

The compressive strength and tensile strength were tested at 7th days, 14th days and 28th day ages. For each mix tests, three specimens were casted. Therefore total of 90 cubes and 90 cylinder specimens were casted.

3.3.4. Curing the specimen

The concrete was casted in the molds for the first 24 hours. After that, the concrete was removed from the molds; the identification code was written on the concrete specimen and cured in water as shown in Figure 3.3 until testing days were reached.

Figure 3.3: (a) Writing the identification code on the specimens (b) Curing in water tank

3.3.5. Test conducted on fresh and hardened concrete properties

Immediately after mixing all the ten concrete mixes, prior to casting the fresh property of concrete, workability was checked by slump cone by filling the cone with three layers and rodding each layers 25 times as shown on Figure 3.4. After measuring slump value the concrete was casted and cured in water tank.

Figure 3.4: Filling the slump test cone with three layers and rodding each layers 25 times

The splitting tensile strength test was carried out on a standard cylinder having 100 mm diameter and 200 mm height was tested on its side in diametral compression. The splitting tensile strength is determined by dividing the maximum applied load by the appropriate geometrical factors. ASTM C-496-04 Standard was followed.

On their testing days, the concrete specimens were removed from the water tank and surface dried. After that in order to determine the unit weight of the concrete specimens the surface dried specimens were weighed prior to test. Both compressive strength and split tensile strength were tested at 7th, 14th and 28th days of curing by compression testing machine as it's shown in Figure 3.5. In each test the averages result of three samples were taken and comparative analysis was made with control concrete and illustrated by graph, tables and figures. Based on this result conclusions were made and recommendations were forwarded.

In this study, ACI 301 specification for structural concrete is used as compliance criteria to compare and identify the river sand moisture contents meet the requirements in concrete production.

Figure 3.5: Compressive strength and split tensile strength test set up

ACI 301 states that; “The strength level of concrete will be considered satisfactory When: the averages of all sets of three consecutive compressive strength test results molded and cured in accordance with the requirements of ASTM C31M equal or exceed fc´ (specified strength); and no individual strength test falls below fc′ by more than 3.5 MPa when fc´ is 35 MPa or less, or by more than 0.1times fc´ when fc´ is more than 35 MPa.”

For early day strength of moist cured concrete ACI 209 gives a formula to calculate the expected compressive strength at specified dates.

$$f'cm(t) = f'cX(\frac{t}{4+0.85t}) \qquad \text{[Eq. 3.1]}$$

Where:

$f'cm(t)$ − Expected mean strength at specified curing date t

$f'cX$ − Specified strength

According to Eq. 3.1 concretes made for this study were expected to attain 17.58 MPa, 22.01 MPa and 25.17 MPa at 7^{th}, 14^{th} and 28^{th} days of curing respectively.

CHAPTER FOUR

RESULTS AND DISCUSSIOS

4.1. Engineering Properties of materials test results

4.1.1. Cement

4.1.1.1. Fineness of cement

The fineness of the cement was found 3% and according to IS Specification, the residue by weight on sieve not to exceed 10 % original weight. This shows the fineness of the cement was within the restriction. Therefore the Dangote OPC used for the investigation satisfies the requirement.

4.1.1.2. Normal consistency of the cement paste

The usual range of water-cement ratio for normal consistency is between 26% and 33%. From the test results, the normal consistency of the cement resulted 31%, which is within these limitations. Therefore the cement used for the research experiment satisfies the requirement.

4.1.1.3. Setting time of the cement paste

The test of the cement paste initial setting time and final setting time resulted 125 minutes and 310 minutes respectively. The Ethiopian standard limits the initial setting time of cement not to be less than 45 minutes and the final setting time not to exceed 10hrs. According to ASTM C 150 initial setting time of cement must not be less than 45 minute and final setting time of cement must not be greater than 375 minutes. EN 197-1:2000 limits the initial setting time for composite Portland cement not to be less than 45 minutes.

Therefore the test results of cement paste used satisfies the requirement of Ethiopian, ASTM and European standards.

4.1.2. Fine Aggregates

4.1.2.1. Particle size distribution of fine aggregate

As it can be seen from Figure 4.1, the gradation of fine aggregate used is within the upper and lower limit of the standards and the fineness modulus (FM) obtained was 2.60. As per ASTM C 33 standard, the fine aggregate fineness modulus must not be less than 2.3 or more than 3.1. The FM obtained was within these limitations i.e. 2.60.

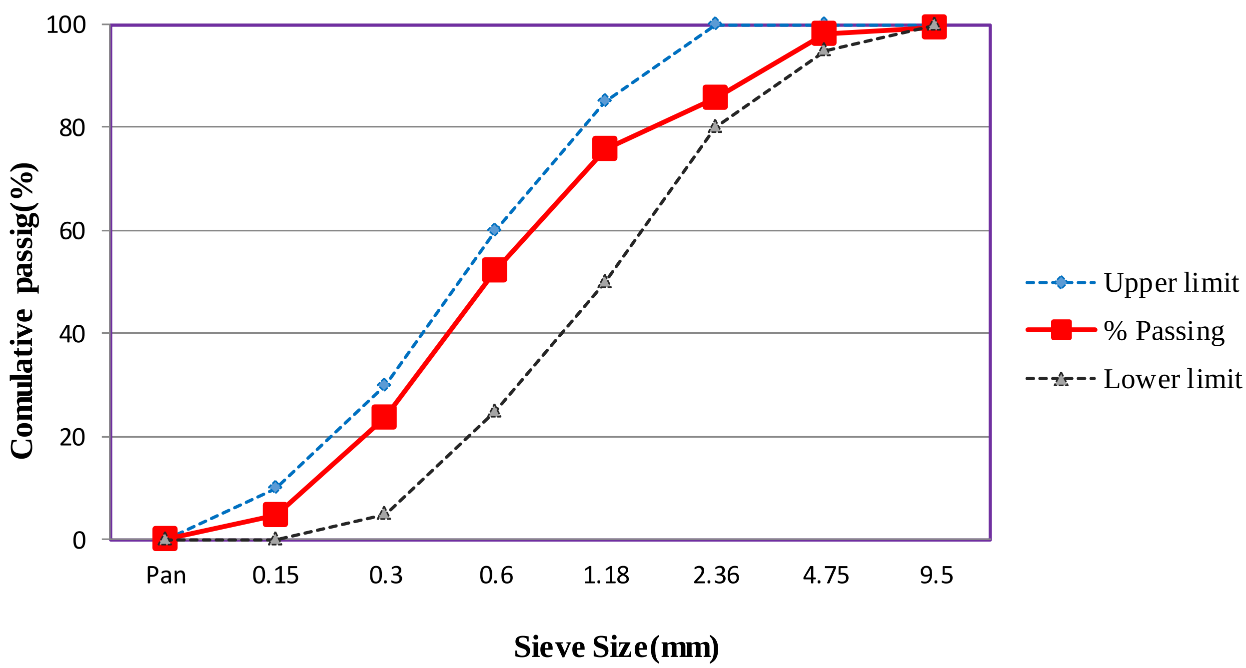

Figure 4.1: Gradation curve of the fine aggregate used with ASTM 33 limit.

$$\text{Therefore Fineness Modules} = \frac{\Sigma \text{ of cumulative coarser (\%)}}{100}$$

$$= \frac{260.25}{100} = 2.6025 = \underline{\underline{2.60}}$$

Therefore, the Gambella river sand sample used for the research study was well graded type of sand.

4.1.2.2. Silt content, specific gravity, absorption capacity, moisture content and unit weight of fine aggregate

Table 4.1 summarizes the laboratory tests results conducted on Gambella river sand used throughout the research work for concrete specimens production.

Table 4.1: Fine aggregate test results summary

No.	Test description		Test result
1.	Silt Content		3%
2.	Fineness Modulus		2.6
3.	Specific gravity	Bulk	2.58
		Bulk (SSD)	2.63
		Apparent	2.72
4.	Moisture Content		2.0%.
5.	Unit weight		1483.82 kg/m^3

Refer Table 4.1, the silt content value of the river sand resulted 3%. ASTM C 33 and Ethiopian standard restrict silt content value to 5% and 6% respectively. This result revels as it keeps the restrictions of ASTM C 33 and Ethiopian standards. Therefore the Gambella river sand used satisfies the standards.

As it can be seen on Table 4.1, the Bulk specific gravity (SSD basis) of fine aggregate used for the testing was 2.63. According to ASTM C 33 aggregate with specific gravity of 2.4-2.8 was classified as normal weight aggregate. Therefore the Gambella river sand used in this research study was normal weight aggregate.

As it can be seen from Table 4.1 the moisture content of Gambella river sand used was 2.0%. As per ASTM C 128 Over a 24-hr period normal weight aggregates may absorb water in the amount of 3 to 10% of their own dry weight, depending on the type of aggregate and its pore structure. This shows that the result obtained was less than the limitation by standard which shows the moisture content of the sand was slight less or the sand was drier.

4.1.3. Coarse Aggregates

4.1.3.1. Particle size distribution of coarse aggregate test results

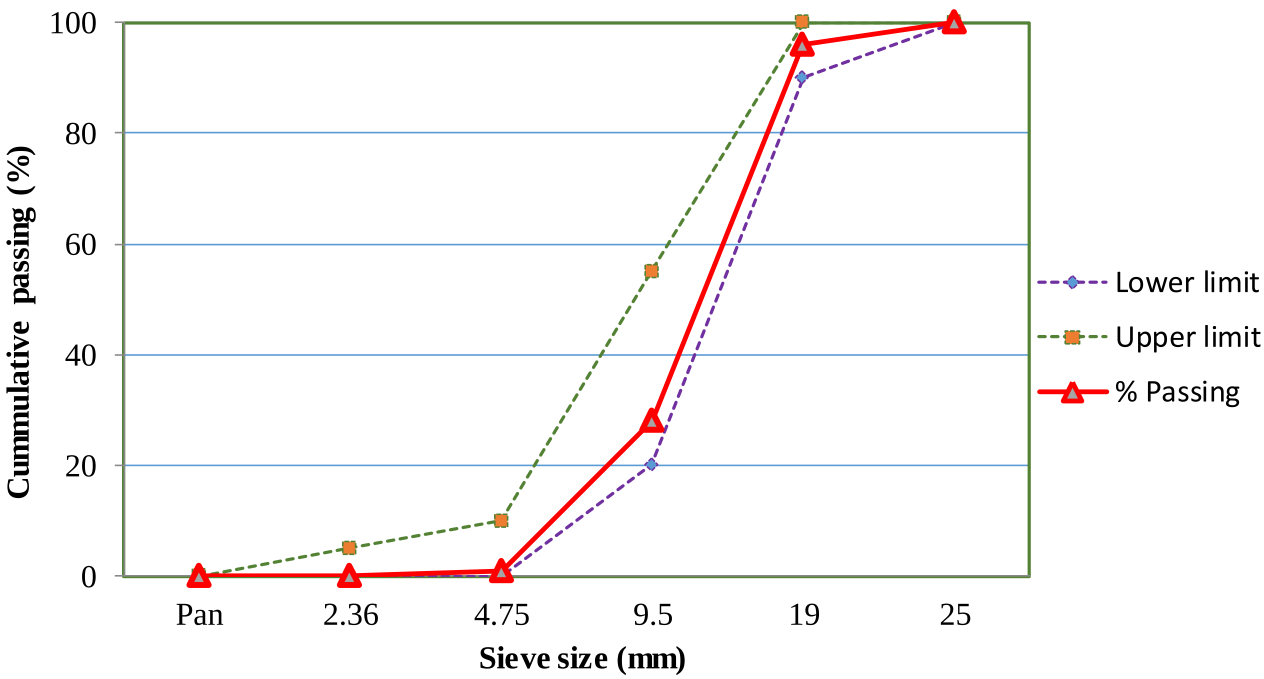

Figure 4.2: Gradation curve of coarse aggregate used with ASTM 33 limit.

As shown on the Figure 4.2, the gradation of coarse aggregate used lays within the upper and lower limit of the ATM 33 - 11 standards. Therefore, the coarse aggregate sample used for the research study was well graded type of aggregate.

4.1.3.2. Unit Weight, Specific Gravity, Moisture content and Absorption

Table 4.2 summarizes the laboratory test results conducted on coarse aggregate used throughout the research work for concrete specimen production.

Table 4.2: Coarse aggregate used test results summary

No.	Test description		Test result
1.	Maximum aggregate size		20mm
2.	Unit weight		1593.63kg/m^3
3.	Specific gravity	Bulk	2.73
		Bulk (SSD)	2.75
		Apparent	2.80
4.	Absorption Capacity		1.259%
5.	Moisture Content		1.005%

4.1.4. Concrete Ingredients proportioning

The compressive strength and tensile strength were tested at 7th days, 14th days and 28th day ages. For each mix tests, three specimens were casted. Therefore total of 9 cubes and 9 cylinder specimens were casted for each ten mixes. Table 4.3shows the weights of concrete ingredients used to cast the cubes and cylinders.

Table 4.3: Weights of the concrete ingredients used to cast the concrete specimens for each mix

No.	Mix Design	Moisture content (%)	Cement (Kg)	Fine aggregate (Kg)	Coarse aggregate (Kg)	Water (kg)
1.	MC1	1%	24.71	53.81	68.49	12.29
2.	MC2	2%	24.71	53.81	68.49	12.29
3.	MC3	3%	24.71	53.81	68.49	12.29
4.	MC4	4%	24.71	53.81	68.49	12.29
5.	MC5	5%	24.71	53.81	68.49	12.29
6.	MC6	6%	24.71	53.81	68.49	12.29
7.	MC7	7%	24.71	53.81	68.49	12.29
8.	MC8	8%	24.71	53.81	68.49	12.29
9.	MC9	9%	24.71	53.81	68.49	12.29
10.	MC10	10%	24.71	53.81	68.49	12.29
Total			**247.10**	**538.10**	**684.90**	**122.90**

4.2. Test results of concrete

4.2.1. Workability of the concrete test results

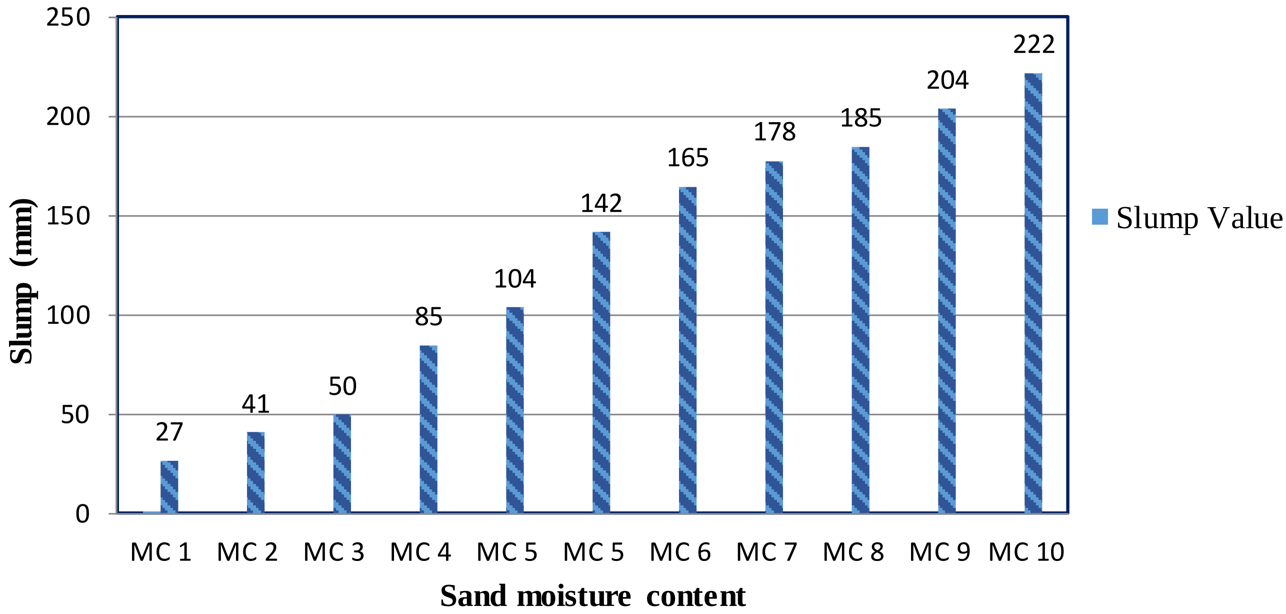

Figure 4.3: Variation of slump of concrete with different sand moisture content

As can be seen from Figure 4.3, the slumps of the concrete containing sand having 1% moisture content was shown a reduction compared to control concrete. While, the slump of the concrete shown increments as sand moisture content increased from 3% to 10%. But, the increments of the slump were not uniform with an increment of sand moisture contents. However, the slumps of sand up to 3% moisture contents resulted within 25-50mm.

Generally, concrete workability was affected by moisture contents of sand used for concrete production. According to [51] Higher the w/c-ratio, the higher will be the water content per unit volume of concrete, which might cause some problems e.g. bleeding, segregation and losing compressive strength. Therefore moisture contents of the river sand should be considered during proportioning to get the required workability of concrete.

4.2.2. Unit weight of the concrete test result

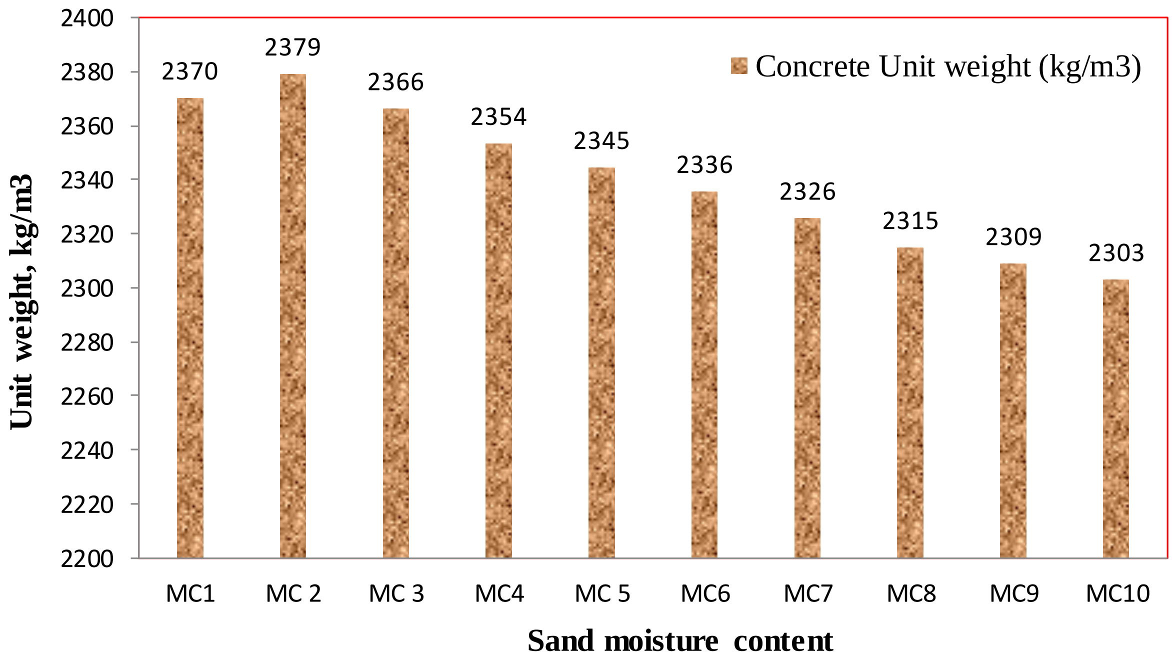

Figure 4.4: Unit weight of Concrete with different sand moisture content

Refer to Figure 4.4, dry density of concrete (28th days) unit weight was decreased as the contents of sand moisture content decreased from 2% to 1% and increased from 2% to 10% compared to control concrete. This implies s the moisture contents of the sand forms pores in concrete. Many researchers also reported as Porosity increased with increased water cement ratio [29, 30, 62]. The probable reason of unit weight reduction of concrete as river sand moisture content increased maybe due to the pores formed in concrete structure.

However, all the densities of the concrete mix exceeded the 1850kg/m^3 which is the maximum density required for lightweight aggregate concrete [41]. Generally, higher moisture contents of river sand in concrete shows lower density concrete which was beneficial in many ways over a high density concrete. This is why the lighter concrete reduces the size of structural members and also reduces the pressure on formworks. Therefore employing higher moisture contents of river sand of concrete could be wise idea which reduces the weight of concrete compared to control concrete in unit weight of concrete aspect.

4.2.3. Compressive strength of the concrete test result

The average compressive strength test results at 7th, 14th and 28th days were presented on Table 4.4 and the test results for all samples were presented on the Annex C.

Table 4.4: Average concrete compressive strength test values and Percentage compressive strength gain with 7th and 14th curing age over 28th day.

No.	Mix Designation	Average Compressive strength, MPa			% compressive strength gain over 28th days		
		7th Days	14th Days	28th Days	7th Days	14th Days	28th Days
1.	**MC1 (1%)**	27.85	30.70	36.14	77.06	84.94	100.00
2.	**MC2 (2%)**	23.10	26.75	29.24	79.02	91.49	100.00
3.	**MC3 (3%)**	21.10	24.38	26.16	80.65	93.19	100.00
4.	**MC4 (4%)**	20.18	23.85	25.27	79.86	94.41	100.00
5.	**MC5 (5%)**	20.09	23.37	24.88	80.75	93.93	100.00
6.	**MC6 (6%)**	19.86	22.41	24.14	82.30	92.84	100.00
7.	**MC7 (7%)**	19.34	21.58	23.47	82.39	91.94	100.00
8.	**MC8 (8%)**	18.53	21.35	22.63	81.86	94.31	100.00
9.	**MC9 (9%)**	17.66	20.70	21.69	81.42	95.43	100.00
10.	**MC10 (10%)**	16.90	20.51	21.31	79.32	96.24	100.00

As shown on the Table 4.4, the compressive strength of all mixes of concrete including control concrete was increased with the curing ages. This was due to increase in hydration process with time which leads to increase the hydration products [41]. Table 4.4 on the right side shows this percentage compressive strength gain with curing age over 28th curing ages.

Refer to Table 4.4, the Control concrete gained 79.02% at 7th day and 91.49% at 14th days of curing over its 28th day compressive strength. The compressive strength gained for MC1 resulted 77.06% at 7th day and 84.94% at 14th days over 28 curing ages. The concrete compressive strength gained increased from 80.65%, 79.86%, 80.75%, 82.30 and 82.39% for MC3, MC4, MC5, MC6 and MC7 respectively and decreased from 81.86%, 81.42% and 79.32% for MC8, MC9 and MC10 respectively at 7^{th} days of curing over its 28^{th} days. For All concrete mix except MC1, the compressive strength gained exceeds the control concrete at 7^{th} days of curing over its 28^{th} days

The compressive strength gained at 14^{th} days for control (MC2) and MC1 resulted 91.49% and 84.94% respectively over its 28^{th} days. The concrete compressive strength gained 93.19%, 94.41%, 93.93%, 92.84%, 91.94%, 94.31%, 95.43% and 96.24% for MC3, MC4, MC5, MC6, MC7, MC8, MC9 and MC10 respectively over its 28^{th} days. For all moisture contents of river sand greater than the control (MC3 to MC10), the strength gained exceeds the control concrete at 14^{th} days over its 28^{th} days.

This observation suggests that the river sand moisture content of 3%, 4%, 5%, 6%, 7%, 8% , 9% and 10% in concrete increases the hydration of cement and provides strengths greater than those of its respective 28th days strength. However the compressive strength of the river sand moisture contents from 3% to 10% resulted less than control concrete at 7^{th}, 14^{th} and 28^{th} days. Numerous researchers have noted the decrease in compressive strength as water/cement ratio contents of concrete increases [23, 24].

Therefore, higher river sand moisture contents level decreases the compressive strength of the concrete. Figure 4.5 shows the change in compressive strength of control concrete and concrete with different moisture contents of concrete in concrete.

As shown on the Figure 4.5, due to an increase in river sand moisture contents, decrease in compressive strength was observed at 7^{th}, 14^{th} and 28^{th} curing ages. Table 4.5 shows these percentages change (increment and reduction) of the compressive strength for each mixes over control concrete i.e. concrete containing 2% river sand moisture content.

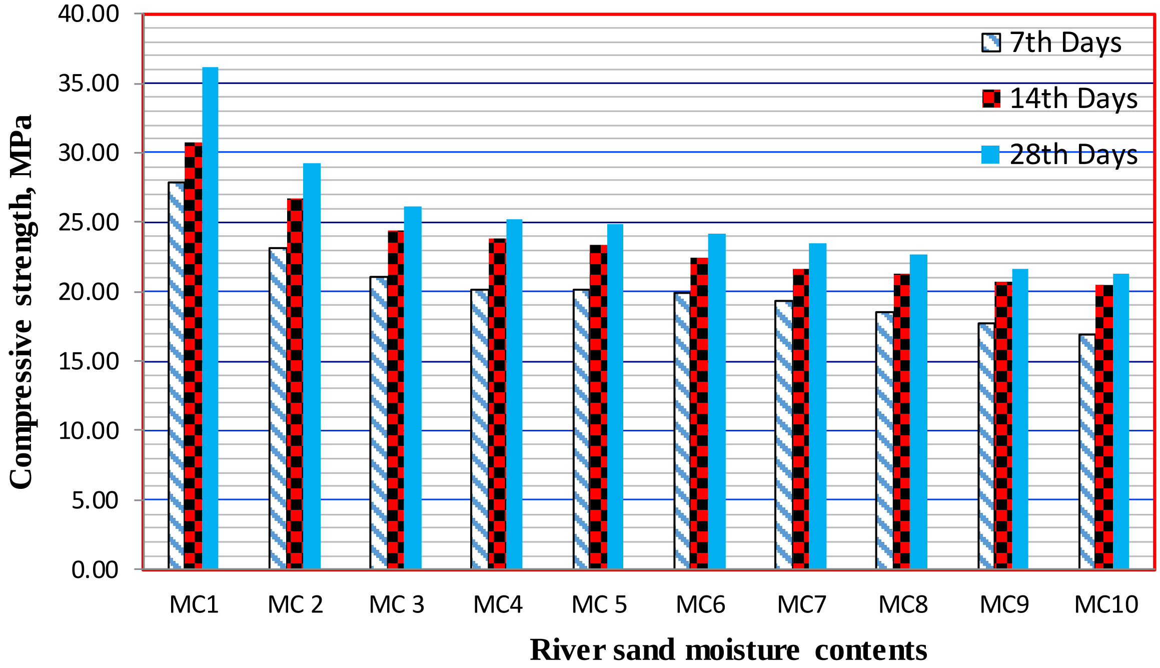

Figure 4.5: Change in compressive strength with 7th, 14th and 28th curing days

Refer to Table 4.5, at 7th curing days the compressive strength of MC1 was increased by 20.57% over control concrete. However, the compressive strength of MC3, MC4, MC5, MC6, MC7, MC8, MC9 and MC10 were 8.66%, 12.65%, 13.04%, 14.01%, 16.28%, 19.80%, 23.54% and 26.84% lower over control concrete respectively.

However, the river sand having moisture content up to 9%(MC9) satisfied ACI 209 criteria, which is for early day strength of moist cured concrete, the expected compressive strength to attain 17.58MPa at 7th days of curing according to Eq. 3.1.

In similar manner at 14th curing days, the compressive strength of MC1 concrete was increased by 14.76% over control concrete. While the compressive strength of MC3, MC4, MC5, MC6, MC7, MC8, MC9 and MC10 were 8.87%, 10.83%, 12.64%, 16.23%, 19.33%, 20.20%, 22.62% and 23.34% lower over control concrete respectively.

Table 4.5: Percentage change in compressive strength of the concrete over control.

No.	Mix Designation	Average Compressive strength, MPa			% compressive strength gain over control concrete		
		7th Days	14th Days	28th Days	7th Days	14th Days	28th Days
1.	**MC1 (1%)**	27.85	30.70	36.14	20.57	14.76	23.60
2.	**MC2 (2%)**	23.10	26.75	29.24	0.00	0.00	0.00
3.	**MC3 (3%)**	21.10	24.38	26.16	-8.66	-8.87	-10.54
4.	**MC4 (4)**	20.18	23.85	25.27	-12.65	-10.83	-13.59
5.	**MC5 (5%)**	20.09	23.37	24.88	-13.04	-12.64	-14.92
6.	**MC6 (6%)**	19.86	22.41	24.14	-14.01	-16.23	-17.45
7.	**MC7 (7%)**	19.34	21.58	23.47	-16.28	-19.33	-19.73
8.	**MC8 (8%)**	18.53	21.35	22.63	-19.80	-20.20	-22.59
9.	**MC9 (9%)**	17.66	20.70	21.69	-23.54	-22.62	-25.81
10.	**MC10 (10%)**	16.90	20.51	21.31	-26.84	-23.34	-27.13

However, the river sand having moisture content up to 6%(MC6) satisfied ACI 209 criteria, which is for early day strength of moist cured concrete, the expected compressive strength to attain 22.01MPa at 14th days of curing according to Eq. 3.1.

At 28th curing days, the compressive strength of MC1 was increased by 23.60% over control concrete. While, the compressive strength of MC3, MC4, MC5, MC6, MC7, MC8, MC9 and MC10 were 10.54%, 13.59%, 14.92%, 17.45%, 19.73%, 22.59%, 25.81% and 27.13% lower over control concrete respectively.

However, the river sand having moisture content up to 4%(MC4) satisfied ACI 209 criteria, which is for early day strength of moist cured concrete, the expected compressive strength to attain 25.17MPa at 28th days of curing according to Eq. 3.1.

These observations reveal that, the compressive strength of the concrete decreases with increasing the moisture contents of river sand at all curing days. This result agrees with the work of [62]. This is due to wet (higher moisture contents of) river sand giving water to the concrete mix.

According to [25], in the concrete with the same unit cement content, hydration can be more activated with larger unit water content. But the consumed water for hydration reaction in cement paste develops to more pores which lead to reduction of strength and resistance to deterioration even in the same hydrate product amount.

From this it can be concluded that the moisture contents of river sand affects the compressive strength of the concrete. Therefore the moisture contents of the river sand should be considered during mix design of concrete.

4.2.4. Tensile strength of the concrete test result

The average tensile strength test results at 7th, 14th and 28th days were presented on Table 4.6 and the test results for all samples were presented on the Annex D.

As shown on the Table 4.6, the tensile strength of all mixes of concrete including control concrete was increased with the curing ages. This was due to increase in hydration process with time which leads to increase the hydration products [41]. Table 4.6 on the right side shows this percentage tensile strength gain with curing age over 28 curing ages for all mixes.

Refer to Table 4.6, the Control concrete gained 70.15% at 7th day and 84.69% at 14th days of curing over its 28th day tensile strength. The tensile strength gained for MC1 resulted 69.98% at 7th day and 84.62% at 14th day. This shows decrease in tensile strength gain at all curing age compared to control concrete i.e. concrete made from sand containing 2% moisture content.

The concrete tensile strength gained increased from 70.45% to 70.93%, for MC3 and MC4 respectively at 7th days of curing over its 28th days. Afterwards, tensile strength gained decreased from 70.27%, 69.81%, 69.53%, 68.94%, 68.61% and 67.61% for MC5, MC6, MC7, MC8, MC9 and MC10 respectively at 7th days of curing over its 28th days. However the tensile strength gain at 7th curing days over its 28th days exceeds the control concrete for MC3, MC4, and MC5.

Table 4.6: Average concrete tensile strength test values and Percentage tensile strength gain with 7th and 14th curing age over 28th day

No.	Mix Designation	Average tensile strength, MPa			% Tensile strength gain over 28th days		
		7th Days	14th Days	28th Days	7th Days	14th Days	28th Days
1.	MC1 (1%)	2.82	3.41	4.03	69.98	84.62	100.00
2.	MC2 (2%)	2.75	3.32	3.92	70.15	84.69	100.00
3.	MC3 (3%)	2.67	3.24	3.79	70.45	85.49	100.00
4.	MC4 (4)	2.66	3.24	3.75	70.93	86.40	100.00
5.	MC5 (5%)	2.60	3.20	3.70	70.27	86.49	100.00
6.	MC6 (6%)	2.52	3.12	3.61	69.81	86.43	100.00
7.	MC7 (7%)	2.35	2.88	3.38	69.53	85.21	100.00
8.	MC8 (8%)	2.22	2.70	3.22	68.94	83.85	100.00
9.	MC9 (9%)	2.12	2.55	3.09	68.61	82.52	100.00
10.	MC10 (10%)	1.92	2.30	2.84	67.61	80.99	100.00

Similarly, the concrete tensile strength gained increased from 85.49%, 86.40% and 86.49 for MC3, MC4 and MC5 respectively at 14th days of curing over its 28th days. Afterwards, tensile strength gained decreased from 86.43%, 85.21%, 83.85%, 82.52%, and 80.99% for MC6, MC7, MC8, MC9 and MC10 respectively at 14th days of curing over its 28th days. However the tensile strength gain at 14th curing days over its 28th days exceeds the control concrete for MC3, MC4, MC5, MC6 and MC7.

This observation suggests that the river sand moisture content of 3%, 4%, and 5%, at 7th days of curing days and river sand moisture content of 3%, 4%, 5%, 6% and 7% at 14th days of curing over its 28th days provides higher tensile strength development. However, the tensile strength of the concrete mixes were less than the control concrete at all curing age except concrete mix made from river sand containing 1% moisture content.

Numerous researchers have noted the decrease in tensile strength as water contents of concrete increases [16]. Therefore, higher river sand moisture contents decreases the tensile strength of the concrete. Figure 4.6 shows the change in tensile strength of control concrete and concrete with different moisture contents of river sand in concrete.

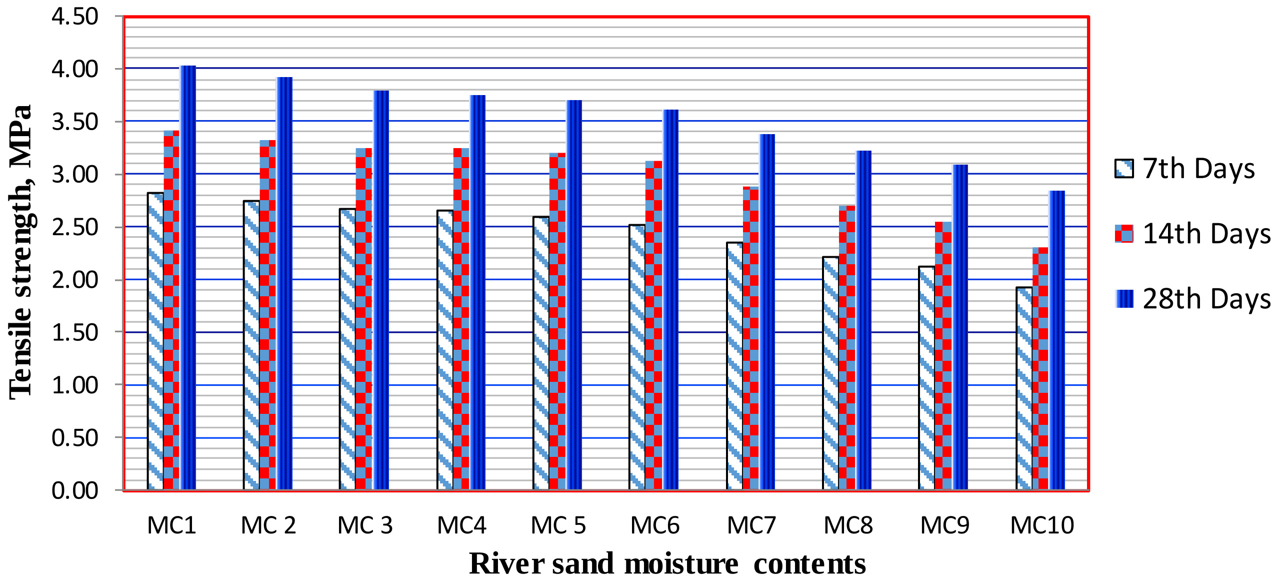

Figure 4.6: Change in tensile strength with 7th, 14th and 28th curing days

As shown on the Figure 4.5, due to an increase in river sand moisture contents, decrease in tensile strength was observed at 7th, 14th and 28th curing ages. Table 4.7 shows these percentages change (increment and reduction) of the tensile strength for each mixes over control concrete i.e. concrete containing 2% river sand moisture content.

Refer to Table 4.7, at 7th curing days the tensile strength of MC1 was increased by 2.55% over control concrete. However, the tensile strength of MC3, MC4, MC5, MC6, MC7, MC8, MC9 and MC10 were 2.91%, 3.27%, 5.45%, 8.36%, 14.55%, 19.2%, 22.91% and 30.18% lower over control concrete respectively.

In similar manner, at 14th curing days, the tensile strength of MC1 concrete was increased by 2.71% over control concrete. While the tensile strength of MC3, MC4, MC5, MC6, MC7, MC8, MC9 and MC10 were 2.41%, 2.41%, 3.61%, 6.02%, 13.25%, 18.67%, 23.19% and 30.72% lower over control concrete respectively.

At 28th curing days, the tensile strength of MC1 was increased by 2.81% over control concrete. While, the tensile strength of MC3, MC4, MC5, MC6, MC7, MC8, MC9 and MC10 were 3.32%, 4.34%, 5.61%, 7.91%, 13.78%, 17.86%, 21.17% and 27.55% lower over control concrete respectively.

Table 4.7: Change in tensile strength at 7th, 14th and 28th curing days over control concrete

No.	Mix Designation	Average tensile strength, MPa			% Tensile strength gain over control		
		7th Days	14th Days	28th Days	7th Days	14th Days	28th Days
1.	**MC1 (1%)**	2.82	3.41	4.03	2.55	2.71	2.81
2.	**MC2 (2%)**	2.75	3.32	3.92	0.00	0.00	0.00
3.	**MC3 (3%)**	2.67	3.24	3.79	-2.91	-2.41	-3.32
4.	**MC4 (4)**	2.66	3.24	3.75	-3.27	-2.41	-4.34
5.	**MC5 (5%)**	2.6	3.2	3.7	-5.45	-3.61	-5.61
6.	**MC6 (6%)**	2.52	3.12	3.61	-8.36	-6.02	-7.91
7.	**MC7 (7%)**	2.35	2.88	3.38	-14.55	-13.25	-13.78
8.	**MC8 (8%)**	2.22	2.7	3.22	-19.27	-18.67	-17.86
9.	**MC9 (9%)**	2.12	2.55	3.09	-22.91	-23.19	-21.17
10.	**MC10 (10%)**	1.92	2.3	2.84	-30.18	-30.72	-27.55

These observations reveal that, the tensile strength of the concrete decreases with increasing the moisture contents of river sand at all curing days. This is due to wet (higher moisture contents of) river sand giving water to the concrete mix.

From this, it can be concluded that the moisture contents of river sand affects the tensile strength of the concrete. However, the effects of the moisture contents of river sand were not significant on tensile strength compared to the compressive strength. Therefore the moisture contents of the river sand should be considered during mixing the concrete on site and kept constant.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

In this research, the influence of Gambella river sand moisture content on concrete was experimentally investigated and depending on the test results obtained the following conclusions were drawn.

The output test results revealed that the properties of the Gambella river sand used throughout this research work confirms the ASTM and Ethiopian code. Therefore it was concluded that Gambella river sand could be used in concrete for different purposes.

The workability of the concrete showed increment as the river sand moisture content increased due to higher water cement ratio as river sand moisture content added water to the concrete mixes. However it was noticed that the workability of the concrete was within 25-50 mm up to 3% river sand moisture content.

Concrete unit weight was slightly decreased as the river sand moisture content increases due to formation of pores in concrete as water content increases from sand moisture contents. Therefore higher moisture contents of river sand could be used in concrete to reduce the unit weight of concrete in concrete weight aspect.

The study of this thesis revealed that the compressive strength of the concrete decreases with increasing the moisture contents of river sand at all curing days. This is due to wet (higher moisture contents of) river sand giving water to the concrete mix. Therefore the moisture contents of the river sand should be considered during mixing of concrete on site.

Split tensile strength showed reduction with increasing the moisture contents of river sand at all curing days. From this it can be concluded that the moisture contents of river sand affects the tensile strength of the concrete. However, the influence of the moisture contents of river sand was not significant on tensile strength compared to the compressive strength. Therefore the moisture contents of the river sand should be considered during mixing on site and kept constant.

5.2. Recommendations

Based on the results of this research investigation, the following recommendations were forwarded:

The compressive strength of concrete is the most important property of concrete used in the design of construction works. The investigation revealed that the compressive strength and Split tensile strength of the concrete decreases with increasing the moisture contents of river sand at all curing days. Therefore, it is important to monitor the river sand moisture content constantly to ensure the accurate w/c-ratio because aggregates contain the largest volume in concrete mix design.

On the other hand, the river sand having moisture content up to 4%(MC4) satisfied ACI 209 criteria, which is for early day strength of moist cured concrete, the expected compressive at 28^{th} days of curing. Therefore concerned bodies should be aware as the river sand moisture content up to 4% could be used without compromising the strength of concrete.

To extend this research to a wider perspective researcher recommends as more studies and research needs to be carried out in this area and the following were recommended for future studies:

The influences of sand and coarse aggregate moisture content from different source on concrete needs to be examined and quantified in future research. The research presented herein only analyzed the influence of river sand moisture content on fresh and hardened concrete.

Detail study of river sand moisture content influence on durability and permeability of concrete should be made.

As the study by [49] showed, Deterioration increased significantly when the water/cement ratio exceeded 0.5, therefore Study should be made on the influence of river sand moisture content on concrete Deterioration.

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ANNEX A MATERIAL TEST RESULTS

A.1. Cement

A.1.1. Fineness of Cement

Calculation

$$\text{Fineness} = \frac{W2}{w1} X100$$

Where:

W1= weight of cement (before sieveing) = 100g.

W2 = weight of residue (after sieving) = 3g.

Result

$$\text{Fineness} = \frac{W2}{w1} X100 \quad \text{Fineness} = \frac{3g}{100g} X100 \quad = 3\%$$

Conclusion

According to IS Specification, the residue by weight retained on sieve not to exceed 10% of original weight. This shows that the fineness of the cement (3%) we got was within the restriction. Therefore the Dangote OPC used for the investigation satisfies the requirement.

A.1.2. Normal consistency of the paste

Calculation

$$\%\text{ of water} = \frac{\text{weight of water in g}}{\text{wight of cement in g}}\ X\ 100$$

Result

The results of the cement normal consistency test results are as follows.

- ✓ Wt. of cement (blended) (g) - 500
- ✓ wt. of water (g) - 155
- ✓ % of water - 31

- ✓ penetration depth (mm) - 9.2

Conclusion

The usual range of water-cement ratio for normal consistency is between 26% and 33%. From the test results, the normal consistency of the cement showed the results within these limitations. Therefore the cement used for the research experiment satisfies the requirement.

A.1.2. Setting time of the cement paste

Result

The results of the cement paste setting time test results are as follows.

- ✓ Initial Setting time (minute) - 125
- ✓ Final Setting time (minute) - 310
- ✓ penetration depth (mm) - 20

Conclusion

The Ethiopian standard limits the initial setting time of cement not to be less than 45 minutes and the final setting time not to exceed 10hrs. According to ASTM C 150 initial setting time of cement must not be less than 45 minute and final setting time of cement must not be greater than 375 minutes. EN 197-1:2000 limits the initial setting time for composite Portland cement not to be less than 45 minutes.

Therefore the test results of cement paste used satisfies the requirement of Ethiopian, ASTM and European standards.

A.2. Fine aggregate

A.2.1. Silt contents

Calculation

Silt content in % = $= \frac{M1-M2}{M1} X\ 100$

Where:

M_1 = original dry mass (total weight)

M_2 = dry mass after washing.

Silt content in % = = $\frac{M1-M2}{M1} X\ 100 = \frac{1-0.97}{1} X\ 100 = 0.03 = 3\%$

The Ethiopian standard restricts the silt content to a maximum of 6%. The fine aggregate, the silt content value resulted 3% which keeps the restrictions of Ethiopian standard. Therefore the fine aggregate used satisfies the standard.

A.2.2. Sieve analysis

Table A.0.1: Sieve analysis requirements of the fine aggregate as per ASTM and test results

sieve size (mm)	Mass retained (kg)	% Retained	cumulative % retained	cumulative % passing	ASTM C 33 Limit (%)	
					Lower limit	Upper limit
9.5	0.015	0.75	0.75	99.25	100	100
4.75	0.02	1	1.75	98.25	95	100
2.36	0.25	12.5	14.25	85.75	80	100
1.18	0.2	10	24.25	75.75	50	85
600mic	0.47	23.5	47.75	52.25	25	60
300mic	0.57	28.5	76.25	23.75	5	30
150mic	0.38	19	95.25	4.75	0	10
pan	0.095	4.75	100	0	-	-
Total	2	100	260.25	-	-	-

A.2.3. Specific gravity and absorption capacity of fine aggregate

Calculation

Bulk specific gravity = $\frac{A}{B+500-C}$

Where:

A = weight of oven dry sample in air, (g)

B = weight of pycnometer filled with water, (g) and

C = weight of pycnometer with sample and water to calibration mark, (g)

Bulk specific gravity = $\frac{A}{B+500-C} = \frac{0.490g}{1555g+500-1865g} = 2.58$

Bulk specific gravity (SSD) = $\frac{500}{B+500-C} = \frac{500}{1555g+500-1865g} = 2.63$

Apparent specific gravity = $\frac{A}{B+A-C} = \frac{490g}{1555g+500-1865g} = 2.72$

Absorption = $\frac{500-A}{A} X\ 100 = \frac{500-490g}{490g} X\ 100 = 0.020 = 2.0\%$

Conclusion

Bulk specific gravity (SSD basis) of fine aggregate used for the testing resulted 2.63. According to ASTM C 33 aggregate with specific gravity of 2.4-2.8 was classified as normal weight aggregate. Therefore the fine aggregate used in this research study was normal weight aggregate.

Table A.0.2: Specific gravity and absorption properties of the sand used

No.	Description of test	Test result
1.	Bulk specific gravity	2.58
2.	Bulk specific gravity (SSD basis)	2.63
3.	Apparent specific gravity	2.72
4.	Absorption capacity	2.0%

A.2.4. Moisture content

Calculation

% moisture content = $\frac{A-B}{B} X\ 100$

Where:

A = weight of original sample (g)

B = weight of oven dry sample (g)

Result

% moisture content = $\frac{500g-490g}{490g} X\ 100 = 0.020 = 2.0\%$

Conclusion

From the calculation the moisture content of fine aggregate resulted 2.0%. As per ASTM C 128 Over a 24-hr period normal weight aggregates may absorb water in the amount of 3 to 10% of their own dry weight, depending on the type of aggregate and its pore structure. This shows that the result obtained was less than the limitation by standard which shows the moisture content of the fine aggregate was slight less or the fine aggregate was drier.

A.3. Coarse aggregate

A.3.1. Sieve analysis

The sieve analysis test of the coarse aggregate used was conducted according to ASTM33- 11 and the corresponding gradation curve along with the recommendations of the ASTM 33 - 11 was shown on Table A.3.

The gradation of coarse aggregate used lays within the upper and lower limit of the ATM 33 - 11 standards. Therefore, the coarse aggregate sample used for the research study was well graded type of aggregate.

Table A.0.3: Sieve analysis results and standard for coarse aggregate

Sieve size (mm)	**Percent passing (ASTM 33)**		**Percent passing (coarse aggregate used)**
	Lower limit	Upper limit	
25	100	100	100
19	90	100	96
9.5	20	55	28
4.75	0	10	1
2.36	0	5	0

A.3.2. Specific gravity and absorption capacity

Calculation

Apparent specific gravity = $\frac{MD}{MD-MW}$

Where:

M_W = weight in water of the saturated aggregate ($W_a - W_b$)

M_{SSD} = weight in air of the saturated surface dry aggregate.

M_D = weight in air of oven drier aggregate.

Result

Apparent specific gravity = $\frac{MD}{MD-MW}$ = $\frac{1.985kg}{1.985kg-1.277kg}$ = 2.80

Bulk specific gravity = $\frac{MD}{MSSD-MW}$ = $\frac{1.985kg}{2.005kg-1.277kg}$ = 2.73

Bulk specific gravity (SSD) = $\frac{MSSD}{MD-MW}$ = $\frac{2.005kg}{2.005kg-1.277kg}$ = 2.75

% water Absorption = $\frac{MSSD-MD}{MD}$ = $\frac{2.005kg-1.985kg}{1.985kg}$ = 1.259%

A.3.3. Moisture content

Calculation

% moisture content = $\frac{A-B}{B} X\ 100$

Where:

A = weight of original sample

B = weight of oven dry sample

Result

% moisture content = $\frac{2000g-1980g}{1980g} X\ 100$ = 1.005%

Table A.0.0.4: Coarse aggregate used test results summary.

No.	Test description		Test result
1.	Maximum aggregate size		20mm
2.	Unit weight		1593.63kg/m^3
3.	Specific gravity	Bulk	2.73
		Bulk (SSD)	2.75
		Apparent	2.80
4.	Absorption Capacity		1.259%
5.	Moisture Content		1.005%

ANNEX B CONCRETE MIX DESIGN AS PER ACI PROCEDURE

Step 1: Choice of slump.

Since the concrete under consideration is C-25 (25Mpa) the concrete may use for structural elements and for mass concrete as well. Therefore, slump range may be estimated (25 - 50mm) is within the recommended values of slump given in the ACI mix design Table 3-7.

Step 2: Maximum aggregate size.

The maximum aggregate size is 20 mm, which meets the limitations given in the ACI mix design

Maximum aggregate size should not be larger than:

- 1/5 the minimum dimension of structural members,
- 1/3 the thickness of a slab, or
- 3/4 the clearance between reinforcing rods and forms. These restrictions limit maximum aggregate size to 1.5 inches, except in mass applications.

Step 3: Estimation of mixing water and air content.

The concrete is not exposed to freezing and thawing; therefore, it must be non-air entrained. From Table 3-8, the recommended mixing water amount is 185kg/m^3, and the approximate entrapped air content is 2%.

Step 4: Water/cement ratio (w/c).

According to Table 3-1, the estimate of the required w/c ratio to give a 28-day compressive strength of 25 MPa is 0.62 and according to Table 3-3 it is 0.5. Taking the minimum i.e. 0.5.

Step 5: Calculation of cement content.

Based on the steps 3 and 4, the required cement content is $\frac{185}{0.5} = 370$kg/m^3.

Step 6: Estimation of coarse aggregate content.

From Table 3-11, for fineness modulus of the fine aggregate of 2.60, the volume of dry rodded coarse aggregate per unit volume of concrete is 0.64.

Therefore, there will be 0.64 m^3 coarse aggregate per m^3 volume concrete. And, the OD weight of the coarse aggregate is;

0.64 $m^3 \times$ 1594kg/ m^3 = 1020.16kg.

From Water absorption for Solids= (SSD weight – OD weight)/OD weight

The SSD weight is = OD weight (Absorption) + OD weight

1020.16(0.01259) + 1020.16 = 1020.16(0.01259+1) =1020.16 x 1.01259 = 1033kg

The SSD weight is 1033kg

Step 7: Estimation of fine aggregate content.

The fine aggregate content can be estimated by either the weight method or the volume method.

Weight method

From Table 3-12, the estimated concrete weight is 2355 kg/m^3. For first trial substituting the values

Ga = (SSD_{coarse} + SSD_{Fine})/2 = (2.75 + 2.63)/2 = 2.69

A = 2% from table 3-8

C_m = 370kg/m^3 from step-5 result

G_c = 3.15

Wm= 185kg/m3 from table 3-8 and estimation in step3

Um = 1oGa(100-A)+Cm(1-Ga/Gc) – Wm(Ga -1) (kg/m3)

= 10(2.69)(100-2) + 370 (1-(2.69/3.15))-185(2.69-1)

= 2377.59kg/m3

≈ 2378 kg/m3

Based on the already determined weights of water, cement, and coarse aggregate, the SSD weight of the fine aggregate is

= 2378 – (185 + 370 +1033)

= **790kg**

Step 8: Adjustment for moisture in the aggregate.

Since the aggregates will be neither SSD nor OD in the field, it is necessary to adjust the aggregate weights for the amount of water contained in the aggregate. Since absorbed water does not become part of the mix water, only surface water needs to be considered.

For the given moisture contents, the adjusted aggregate weights become:

- **Coarse aggregate (stock):**

From W (stock) = W (OD) (1 + MC (OD))

W (stock) = 1020.16 (1 + 0.005)

= 1020.16 x 1.005= 1025.26kg ≈ 1026kg

The extra water needed for coarse aggregate absorption is

W (SSD) −W (stock) = 1033 − 1026 = 7kg

- **Fine aggregate (stock):**

From W (stock) = W (OD) (1 + MC (OD))

=790 × 1.020 = 805.8 kg/m^3 ≈ 806kg/ m^3

Extra water provided by fine aggregate: 806 − 790 = 16kg

The mixing water is then: 185 + 7 −16 = 176 kg

Thus, the estimated batch weights per m^3 are as follows:

N0.	Ingredient	weight	Ratio
1.	cement	370 kg	1
2.	Fine aggregate	806kg	2.17
3.	coarse aggregate	1026 kg	2.77
4.	water	176 kg	0.48
	Total	**2378kg**	

Step 9: Trial mixes.

Trial mixes should be carried out using the proportions calculated. The properties of the concrete in the trial mix must be compared with the desired properties, and the mix design must be corrected as described. Trial mixes are made to check the validity of the concrete design. The calculated mix proportions should be checked by making trial mixes. Only a sufficient amount of water to produce the required workability should be used, regardless of the amount calculated.

For this mix designed calculated in step 8, the trial mix was prepared for strength of 25MPa with water to cement ratio of 0.48 and a cement content of 370kg/m3. The trial mix resulted in a slump of 16mm and a seven day compressive strength of 23.86MPa. The slump of the concrete was below the targeted slump which is 25-50mm.

For the purpose of preparing a final mix the water to cement ratio of the mix requires increasing. Sidney Mindess et al [55] suggested that an increase or decrease of the water content by 6kg/m3 will increase or decrease the slump by approximately 25mm. Depending on this water to cement ratio of the mix was increased to 0.50 from 0.48 by keeping the cement content constant i.e. water increased from 176kg/m3 to 184kg/m3 to make the slump less than the upper limit which is 50mm and resulted 41mm which is within the target slump (25-50mm).

To know the compressive strength of 28 days it needs to wait for 21 more after testing for 7 days. But, Sidney Mindess et al [55] suggested that the ratio of the 28 days strength to the 7 days strength lies between 1.3 and 1.7 but is usually less than 1.5 and it depends on the cement type and curing temperature. Using this, seven day compressive strength was used to extrapolate the 28 days compressive strength taking 1.5 as the extrapolation factor. From this 28 day compressive strength will be around 35.80MPa which is higher than the targeted value.

Therefore, the adjusted batch weights per m^3 of concrete were as follows:

N0.	Ingredient	weight	Ratio
1.	cement	370 kg	1
2.	Fine aggregate	806kg	2.17
3.	coarse aggregate	1026 kg	2.77
4.	water	184 kg	0.50
	Total	**2378kg**	

ANNEX C COMPRESSIVE STRENGTH TEST RESULTS

ANNEX C.1: 7th Days Compressive strength test results

No.	Name	Dimension (mm) L	W	H	Weight (kg)	Failure Load(N)	Compressive strength (Mpa)
1	MC1	148.5	150.5	151.5	8.23	622.22	27.65
2		152.0	149.0	149.0	8.12	638.45	28.38
3		149.0	151.5	150.5	8.48	619.11	27.52
Average					**8.27**		**27.85**
1	MC2	150.5	151.5	149.5	8.36	531.12	23.61
2		152.0	149.0	149.0	8.49	510.12	22.67
3		149.0	152.0	151.0	8.44	518.12	23.03
Average					**8.43**		**23.10**
1	MC3	149.5	151.5	149.0	8.08	480.11	21.34
2		150.5	151.5	149.0	8.29	478.15	21.25
3		148.5	150.5	151.5	8.56	466.01	20.71
Average					**8.31**		**21.10**
1	MC4	150.5	151.5	149.0	8.45	445.11	19.78
2		152.0	149.0	149.0	7.99	453.22	20.14
3		148.5	150.5	151.5	8.09	463.88	20.62
Average					**8.17**		**20.18**
1	MC5	149.0	151.5	150.5	8.01	452.12	20.09
2		152.0	149.0	149.0	8.07	462.14	20.54
3		149.0	152.0	150.0	8.22	441.88	19.64
Average					**8.10**		**20.09**
1	MC6	152.0	149.0	149.0	8.23	444.44	19.75
2		149.0	151.5	150.5	8.10	440.55	19.58
3		150.5	151.5	149.0	8.01	455.88	20.26
Average					**8.11**		**19.86**
1	MC7	148.5	150.5	151.5	8.10	438.11	19.47
2		149.0	152.0	149.0	8.12	442.58	19.67
3		152.0	149.0	149.0	7.90	424.88	18.88
Average					**8.04**		**19.34**
1	MC8	150.5	151.5	149.0	7.85	418.88	18.62
2		149.5	152.0	149.0	7.88	418.48	18.60
3		149.0	151.5	150.5	7.66	413.22	18.37
Average					**7.80**		**18.53**
1	MC9	148.5	150.5	151.5	7.56	408.08	18.14
2		152.0	149.0	149.0	7.62	388.45	17.26
3		149.0	152.0	149.5	7.66	395.55	17.58
Average					**7.61**		**17.66**
1	MC10	149.0	151.5	150.5	7.62	384.68	17.10
2		148.5	150.5	151.5	7.51	386.67	17.19
3		152.0	149.0	149.0	7.48	369.42	16.42
Average					**7.54**		**16.90**

ANNEX C.2: 14th Days Compressive strength test results

No.	Name	Dimension (mm) L	W	H	Weight (kg)	Failure Load(N)	Compressive strength, (Mpa)
1	MC1	148.5	150.5	151.5	8.12	704.11	31.29
2		149.0	151.5	150.5	8.05	688.48	30.60
3		152.0	149.0	149.0	8.21	679.45	30.20
Average					**8.13**		**30.70**
1	MC2	150.5	151.5	149.0	8.62	600.22	26.68
2		149.0	152.0	150.5	8.30	612.44	27.22
3		148.5	150.5	151.5	8.38	593.14	26.36
Average					**8.43**		**26.75**
1	MC3	149.0	152.0	149.0	8.10	552.01	24.53
2		150.5	151.5	149.0	7.98	555.15	24.67
3		149.0	150.0	151.5	8.49	538.48	23.93
Average					**8.19**		**24.38**
1	MC4	149.0	152.0	150.0	8.10	535.54	23.80
2		152.0	149.0	149.0	8.19	532.22	23.65
3		150.5	151.5	149.0	8.23	542.41	24.11
Average					**8.17**		**23.85**
1	MC5	148.5	150.5	151.5	8.01	530.48	23.58
2		152.0	149.0	149.0	8.36	518.88	23.06
3		149.0	151.5	150.5	7.88	528.44	23.49
Average					**8.08**		**23.37**
1	MC6	148.5	150.5	151.5	7.66	512.22	22.77
2		150.5	151.5	149.0	7.65	502.14	22.32
3		149.0	152.0	150.0	7.60	498.44	22.15
Average					**7.64**		**22.41**
1	MC7	149.0	152.0	150.0	7.40	495.48	22.02
2		152.0	149.0	149.0	8.15	488.44	21.71
3		150.5	150.0	150.0	7.30	472.46	21.00
Average					**7.62**		**21.58**
1	MC8	149	152	150	7.20	463.22	20.59
2		148.5	150.5	151.5	7.98	485.66	21.58
3		149	151.5	150.5	7.44	492.22	21.88
Average					**7.54**		**21.35**
1	MC9	152.0	149.0	149.0	7.68	462.22	20.54
2		150.0	151.0	150.5	7.41	474.66	21.10
3		150.5	151.5	149.0	7.23	460.44	20.46
Average					**7.44**		**20.70**
1	MC10	148.5	150.5	151.5	7.24	460.44	20.46
2		149	151.5	150.5	7.23	470.28	20.90
3		152.0	149.0	149.0	7.22	454.00	20.18
Average					**7.23**		**20.51**

ANNEX C.3: 28th Days Compressive strength test results

No.	Name	Dimension (mm)			Weight (kg)	Failure Load(N)	Compressive strength (Mpa)
		L	W	H			
1		150.5	149	149.5	8.05	822.02	36.53
2		149	150	150.5	7.64	802.88	35.68
3	**MC1**	150	150.5	149	8.31	814.54	36.20
Average					**8.00**		**36.14**
1		150.5	149	150	8.12	665.55	29.58
2		149	150	150.5	7.88	644.56	28.65
3	**MC2**	150.5	150	149	8.10	663.44	29.49
Average					**8.03**		**29.24**
1		149	150.5	150	7.88	600.22	26.68
2		150.5	149	149	7.98	582.72	25.90
3	**MC3**	150	150.5	150	8.10	583.11	25.92
Average					**7.99**		**26.16**
1		150.5	150	149	7.89	538.15	23.92
2		150	149	150.5	8.06	575.44	25.58
3	**MC4**	150.5	150	149	7.88	592.44	26.33
Average					**7.94**		**25.27**
1		150	150	150	8.00	572.44	25.44
2		150.5	150.5	150	7.64	555.03	24.67
3	**MC5**	150	150	150.5	8.10	552.14	24.54
Average					**7.91**		**24.88**
1		149	150	149	8.12	545.41	24.24
2		150	149	150	7.76	541.11	24.05
3	**MC6**	149	150	149	7.77	543.22	24.14
Average					**7.88**		**24.14**
1		150.5	150	150.5	8.02	522.36	23.22
2		150.55	150	149	7.85	534.64	23.76
3	**MC7**	150	149	150.5	7.68	527.55	23.45
Average					**7.85**		**23.47**
1		150	150.5	150	7.88	501.44	22.29
2		150.5	150	149	7.64	500.12	22.23
3	**MC8**	150	150.5	150	7.92	525.88	23.37
Average					**7.81**		**22.63**
1		150.5	150	150.5	7.85	482.66	21.45
2		150.5	150	149	7.72	494.28	21.97
3	**MC9**	150	149	150	7.81	486.88	21.64
Average					**7.79**		**21.69**
1		150	149	150	7.68	490.44	21.80
2		149	150.5	149	7.86	474.86	21.10
3	**MC10**	150.5	150	150.5	7.78	472.92	21.02
Average					**7.77**		**21.31**

ANNEX D TENSILE STRENGTH TEST RESULTS

ANNEX D.1: 7th Days Tensile strength test results

Name	No.	Failure Load(N)	Tensile strength (Mpa)
MC1	1	82.00	2.61
	2	94.25	3.00
	3	89.00	2.83
Average			**2.82**
MC2	1	78.10	2.49
	2	92.00	2.93
	3	89.00	2.83
Average			**2.75**
MC3	1	72.14	2.30
	2	92.01	2.93
	3	87.68	2.79
Average			**2.67**
MC4	1	77.22	2.46
	2	84.00	2.68
	3	86.00	2.74
Average			**2.62**
MC5	1	76.66	2.44
	2	88.64	2.82
	3	79.89	2.54
Average			**2.60**
MC6	1	73.24	2.33
	2	85.55	2.72
	3	81.40	2.59
Average			**2.55**
MC7	1	78.00	2.48
	2	70.24	2.24
	3	73.00	2.32
Average			**2.35**
MC8	1	77.00	2.45
	2	64.48	2.05
	3	74.00	2.36
Average			**2.29**
MC9	1	68.44	2.18
	2	74.66	2.38
	3	64.44	2.05
Average			**2.20**
MC10	1	67.88	2.16
	2	62.68	2.00
	3	55.88	1.78
Average			**1.98**

ANNEX D.2: 14th Days Tensile strength test results

Name	No.	Failure Load(N)	Tensile strength (Mpa)
MC1	1	114.30	3.64
	2	106.66	3.40
	3	102.00	3.25
Average			**3.43**
MC2	1	98.99	3.15
	2	104.65	3.33
	3	108.64	3.46
Average			**3.32**
MC3	1	88.88	2.83
	2	101.20	3.22
	3	114.20	3.64
Average			**3.23**
MC4	1	106.64	3.40
	2	102.00	3.25
	3	89.89	2.86
Average			**3.17**
MC5	1	88.66	2.82
	2	96.66	3.08
	3	108.66	3.46
Average			**3.12**
MC6	1	88.45	2.82
	2	103.44	3.29
	3	98.84	3.15
Average			**3.09**
MC7	1	98.00	3.12
	2	95.00	3.03
	3	78.00	2.48
Average			**2.88**
MC8	1	88.00	2.80
	2	78.46	2.50
	3	92.41	2.94
Average			**2.75**
MC9	1	87.68	2.79
	2	78.45	2.50
	3	80.22	2.55
Average			**2.62**
MC10	1	87.48	2.79
	2	72.14	2.30
	3	66.88	2.13
Average			**2.40**

ANNEX D.3: 28th Days Tensile strength test results

Name	No.	Failure Load(N)	Tensile strength (Mpa)
MC1	1	126.48	4.03
	2	128.32	4.09
	3	124.85	3.98
Average			**4.03**
MC2	1	122.23	3.89
	2	128.65	4.10
	3	118.15	3.76
Average			**3.92**
MC3	1	125.00	3.98
	2	118.26	3.77
	3	114.20	3.64
Average			**3.79**
MC4	1	122.21	3.89
	2	129.00	4.11
	3	102.00	3.25
Average			**3.75**
MC5	1	121.00	3.85
	2	118.90	3.79
	3	108.46	3.45
Average			**3.70**
MC6	1	114.60	3.65
	2	120.45	3.84
	3	104.86	3.34
Average			**3.61**
MC7	1	114.30	3.64
	2	105.67	3.37
	3	98.00	3.12
Average			**3.38**
MC8	1	98.10	3.12
	2	107.69	3.43
	3	98.00	3.12
Average			**3.22**
MC9	1	107.06	3.41
	2	95.42	3.04
	3	89.00	2.83
Average			**3.09**
MC10	1	78.94	2.51
	2	99.89	3.18
	3	89.00	2.83
Average			**2.84**

ANNEX E SAMPLES OF PHOTOS TAKEN DURING THE RESEARCH

Figure E.1: Sieve analysis of aggregate samples used

Figure E.2: Moulding and demolding of concrete specimens

Figure E.3: Air drying concrete specimen prior to testing

Figure E.4: Measuring concrete specimen weight

Figure E.5: Compressive strength and tensile strength test set up

Figure E.6: Concrete specimen after testing