ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTES OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Effect of Fines Modulus of Crushed Sand on the Mechanical Properties of Concrete.

By

Asres Teshome

A Thesis submitted to the School of Graduate Studies of Addis Ababa University
In partial fulfillment of the requirement for the Degree of Master of

Science in Civil Engineering
(Structural Engineering Stream)

Advisor: Dr. Girma Zerayohannes

July, 2021

Addis Ababa, Ethiopia

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DECLARATION

I, the undersigned declare that this thesis entitled “Effect of Fines Modulus of Crushed Sand on the Mechanical Properties of Concrete” is my original work, prepared under the guidance of **Girma Zerayohannes (Dr.)**. All sources of material used for this research have been dually acknowledged. Moreover, this thesis has not been presented by any other person in this or any other university or higher educational institute for an award of a degree.

Asres Teshome

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Date: ____________________

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ABSTRACT

This experimental study is to investigate the optimum fineness modulus range of crushed sand to be used in concrete mixes. For compressive strength determination of the hardened concrete, 45 concrete cubes and for flexural strength determination, 30 concrete simple beam specimen were prepared for testing. Five different fineness moduli and grading were tested 2.2, 2.5, 2.8, 3.0 and 3.2. All concrete cubes were left in curing until testing at the age of 7, 28 and 56 days respectively whereas the simple beam specimen were left in curing for the age of 7 and 28 days. Samples were loaded to failure and the average compressive and flexural strength was used for comparison purposes. To measure the workability of fresh concrete mixes, slump test had been used directly after mixing. Results confirmed that the optimum fineness modulus range for the crushed sand to be used as fine aggregate in the concrete mix to get maximum compressive and flexural strength is from 2.6 to 3.0. The slump test revealed an increment in the workability of fresh concrete with higher fineness modulus of crushed sand used in the concrete mix. The slump measure for the optimum fineness modulus is in the range of the recommended slump value which makes a workable mix. All finely crushed sand used in this research study checked to match the ASTM grading requirements for fine aggregate.

Key words: Concrete, Aggregate, Crushed Rock Sand, Fineness Modulus, Compressive Strength, Flexural Strength.

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ACRONYMS

AAiT	Addis Ababa Institute of Technology
AAU	Addis Ababa University
ACI	American Concrete Institute
ASTM	American Standard for Testing and Measurement
CA	Coarse Aggregate
CR	Crushed Rock
Dr.	Doctor
ERA	Ethiopian Road Authority
ES	Ethiopian Standard
FA	Fine Aggregate
F.M	Fineness Modulus
gm	Gram
gm/cm^3	Gram per cubic centimeter
In	Inch
Kg/m^3	Kilo gram per cubic meter
Km	Kilometer
KN	Kilo Newton
mm	Millimeter
MPa	Mega Pascal
R^2	R Square it is Coefficient determination
W/C	Water Cement Ratio
µm	Micrometer

CHAPTER ONE

Introduction

1.1 Background

The concrete is a composite material which is predominantly used all over the world. The quality of good concrete is dependent mainly on the quality of its constituent materials. The strength characteristics of concrete also depend upon the properties of constituent material and their combined action. It is a known fact that concrete making aggregates constitute the lion share of the total volume of concrete.

In addition to quality, one extremely important factor in concrete production is consistent supply of the coarse and fine aggregates. In this regard, a coarse aggregate is produced by crushing basaltic stone, and river sand is the major natural resource of fine aggregate in Ethiopia. However, the intensive construction activity is resulting in a growing shortage and price increase of the natural sand in Ethiopia. In addition, the aggregate and concrete industries are presently facing a growing public awareness related to the environmental influence of their activities and river sand is also scarce. In general consumption of natural sand is high, due to the large use of concrete and mortar. Hence the demand of natural sand is very high in developing countries to satisfy the rapid infrastructure growth. The developing country will face shortage of good quality of natural river sand. Therefore the need to find an alternative concrete and mortar aggregate material to river sand in construction works has assumed greater importance now a days. Researcher and Engineers have come out with their own ideas to decrease or fully replace the use of river sand and use recent innovations such as manufactured sand, robot silica or sand, stone crusher dust, filtered sand, treated and sieved silt removed from reservoirs as well as dams besides sand from other water bodies [1].

Fine aggregate is one of the important constituent materials as far as strength characteristics of concrete are concerned. Natural aggregates such as sand from sea, river, dune or crushed fine stone are generally used in concrete as fine aggregates. Increase in demand and decrease in natural sources of fine aggregate for the production of concrete has resulted in the need to identify new sources of fine aggregate. River sand which is most commonly used as fine aggregate in the production of concrete and mortar poses the problem of acute shortage in many areas. Dune sand is very fine, consequently, it cannot be used alone as fine aggregate in the concrete mixes. Using the dune sand alone could adversely affect properties of concrete in terms of workability, compressive strength and bond. One possible alternative material that can be used as a replacement for natural river sand is the use of crushed rock (CR) sand (manufactured sand). At same time increasing quantity of crushed stone dust (CR sand) is available from crusher as waste. The disposal of this dust is serious environmental problem. If it is possible to use this CR sand in making concrete and mortar by partial or full replacement of natural river sand then this will not only save the cost of construction but at the same time will solve the problem of disposal of this dust. For satisfactory utilization of this alternative material, the various phases of examination have to be: technical feasibility, durability of processed concrete and economic feasibility.

Therefore, the purpose of this study will directly focus on evaluating the fines modulus (F.M) of CR Sand from quarry site in fully replacing river sand in a concrete design. Concrete made with different percentages of CR sand in the mix was investigated and reported considerable effect on different properties of concrete in terms of workability, air content, compressive strength, flexural strength, absorption, and water permeability [2]. Other experimental study investigated the effect of partial to full replacement of natural river sand with crushed rock sand on the workability, compressive strength and flexural strength of concrete [3]. The investigation included testing of compressive, flexural strength and workability of same concrete mix, but with different grading for the fine CR sand used (F.M from 2.2 to 3.2). In this study the compressive strength of concrete was tested using standard cubes and flexural strength of concrete is using simple beam with third-point loading method to determine optimum fineness modulus. While, the results of workability, using slump test. Finally, from the results conclusions were made and recommendations were forwarded.

1.2 Statement of the problem

The current booming construction industries demand large reserves of construction materials and skilled workmanship. Having the luxury of abundant construction materials is one of the manifestations of a great construction industry. Sand is one of the main construction materials. Rapid and constant usage of river sand is leading to environmental problems associated with its depletion.

Moreover, the sources of this river sand are located several hundreds of kilometer away from the capital, where the majority of the construction industry sector is located. When we look the current availability and condition of river sand in Ethiopia, one can easily see that it is an alarming issue. Therefore, it is mandatory to identify alternative sources of sand and study whether it can be as effectively used as a replacement for natural sand. To this regard, one possible alternative material that can be used as a replacement for natural sand is the use of CR sand. Due to the shortfall in the supply of natural sands and the increased activity in the construction sector, it is the time to use CR sand as an ingredient in concrete production.

For the most part, most countries specially Ethiopia were focused on how to determine fines modulus of CR sand or natural river (sea) sand for preparation of concrete mixes instead of determining the effects of optimum fines modulus of fine CR on concrete compressive, flexural strength and workability.

1.3 Objectives

1.3.1 General

This research aims to give an overview to evaluate the effect of fines modulus of crushed sand on concrete properties.

1.3.2 Specific

This research will focus mainly on, finding the optimum range of fines modulus for crushed sand to determine the concrete compressive, flexural strength and workability.

1.4 Scope and Limitation

1.4.1 Scope

The local construction industry in Ethiopia, like other country, has been using river sand for many decades. In fact, the experience of most concrete producers in Ethiopia is based mainly on the use of river sand. With river sand changed to crushed rock sand, which may have different characteristics; it takes time for the local construction industry to adapt. Hence, apart from identifying suitable river sand substitutes to supplement or even completely replace river sand, it is important also to evaluate the fineness modulus of the CR sand and the possible effects using the CR sand on the performance of the concrete. Therefore the main focus of this thesis is to find the optimum range of fineness modulus for crushed rock sand with completely replacing river sand as a fine aggregate in concrete mix. The investigation is an attempt to evaluate the characteristics of concrete using CR sand as fine aggregate.

1.4.2 Limitation

This research have limitation of investigating crushed rock sand for mortar and effect of it on shrinkage of concrete.

1.5 Research Significance

The successful completion of this research will have significance for the production of concrete by:

- Assisting the current fast growing construction industry by providing an alternative to the widely used river sand.
- Making our structure an economical cost without compromising the strength.
- Giving valuable information for aggregate quarries, manufactures, suppliers, and concrete producers in order to improve the different properties of the concrete mixes in terms of compressive, flexural strength and workability without extra cost by providing the fine crushed sand to the construction market with fineness modulus.

1.6 Research Methodology

The following methodology has been employed to achieve the objectives of the research:

- Literature survey, which includes strength of concrete, way of aggregate gradation , properties and tests on fresh and hardened concrete, factors and mixing of concrete. The review includes text books, periodicals and academic journals, seminars and research papers.
- Sample preparation using different fineness modulus for fineness aggregates part.
- Performing different tests on fresh and hardened state, including workability for fresh concrete, compressive strength at 7, 28 and 56 days and for flexural tests at 7 and 28 days on the hardened concrete.
- Analysis of the test results in which the results were presented and discussion were made on the research findings.
- And finally formulation of conclusion and recommendations based on the results obtained.

1.7 Organization of the Research

This research is structured with five chapters and further break down in to different sections and sub sections. An introduction is provided with Background, statement of the problems, objectives, significance, and methodology of the study in the first chapter. The second chapter consists of the fundamentals of concrete and its constituents and requirement of fine aggregate by referring and reviewing different literatures. Designing property of concrete mixtures and its manufacturing process, the properties of the fresh and hardened concrete and its control tests are the main highlight of this chapter. Chapter three will be focusing on the materials properties and experimental programs of the research. It will discuss the properties of materials used for the production of concrete, mix proportions selected, specimen preparation, and testing procedures. Chapter four deals with test results obtained from the experimental study and gives discussion based on the findings. It will illustrate and explain in detail the significance and meaning of each result. This will be followed by the last chapter, chapter five, which states the conclusions and recommendations derived from the research. Finally a list of reference material used to assist this research and listed together with annexes showing detailed test procedures and results. A photographic presentation is also attached in the annex.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Concrete is the most commonly used modern construction materials. It forms the basis of the modern construction system. Many of our activities directly or indirectly are affected by concrete structures; the buildings we live and work in, the roads we drive on, the dams from which we get water and energy, etc. can be an example. The ability of concrete to be cast into any desired shapes and configurations is the reason for its versatility.

The word concrete comes from a Latin word concretus which means to grow together [4], which implies that it is a composite of different materials. It is composed of granular material called aggregate or filler which is embedded in a hard matrix of material (cement or binder with water) binding the aggregates together and filling the space formed between them. When the constituents are mixed with water the concrete solidifies and hardens due to a chemical reaction between the water and the cement called hydration, which finally forms a stone like material by binding the aggregates together.

Concrete is mainly composed of cement, aggregate and water. Cementitious materials, filler materials, chemical admixtures, and some other additives may also be the constituents of concrete depending on the need and their availability. All the constituents have their own purpose in the concrete. Cement with water acts as a binding medium in which the aggregates which accounts 65 to 75 percent of the concrete are bound together to form the concrete [5]. Economy, dimensional stability and wear resistance are the main reasons behind using aggregates. Different types of admixtures are used to modify the properties of ordinary concrete so as to make it suitable for any situation.

If a concrete is to be suitable for a particular purpose, it is necessary to select the constituent materials and combine them in such a manner as to develop the special qualities required as economical as possible. Therefore the selection of constituents of concrete depends on the quality and economy of the particular concrete required.

2.2 Strength of concrete

2.2.1 Strength of Hardened concrete

Strength of concrete is commonly considered as the most valuable property, although in many practical cases other characteristics, such as durability and permeability, may in fact be more important. The strength of concrete is dependent on many things. The hydration reaction, water to

Cement ratio, aggregate type, amount and size, water content, cement content, curing condition, cement type, compaction method used etc. 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 increases the strength of the concrete. The water required for the hydration reaction is less than that of the mixing water; the extra water provided is used to make the concrete more workable. The compaction of the fresh concrete reduces the amount of entrapped air and therefore increases the strength of the concrete. It is found that for each 1 % of air entrapped there will be a 5 to 6 % loss on strength [6]. Curing temperature affects the hydration of cement and hence the duration of strength gains. Cubes kept at about 10^{o}C will have their 7 day strength reduced by 30% and their 28 day strength by 15% [6].

2.2.1.1 Compressive Strength of concrete

The main measure of the structural quality of concrete is its compressive strength. In addition, it has a great practical and economic significance because the sections and sizes of the concrete structures are determined by it.

Since most concrete structures are designed to resist compressive stress, it is this property which is usually prescribed by codes or standards in terms of either ultimate strength or working stress which is taken as a percentage of the crushing strength as determined by standard cube tests.

The compressive strength is calculated from failure load divided by cross-sectional area resisting the load and reported in units of force per square area. Concrete is graded based on tests of 150 mm cubes at the age of 28 days which may be considered as the characteristic cube compression strength in MPa [7].

Compressive Strength can be increased by:

- Decreasing W/C ratio
- Using high strength aggregates because that makes 65-75% of the volume of concrete.
- Grading the aggregates to produce a small percentage of voids in the concrete
- Moist curing the concrete after it has set
- Vibrating the concrete in the forms while plastic

2.2.1.2 Tensile strength of Concrete

Even though compression strength of concrete is best utilized, its tensile strength is also important in a variety of items. It is used to design for shear, torsion and crack width. This is much lower than compressive strength. It is difficult to determine from tension test due to problem with gripping and is indirectly determined from split-cylinder test or flexure test (modulus of rupture) or from empirical formulae.

2.2.1.3 Factors affecting the Strength of Concrete

The strength of concrete is affected by a number of factors. The most important being the water-cement ratio and the degree of compaction. Other factors include the components of materials (cement and aggregates), the age and curing condition, fineness modulus of fine aggregate.

2.2.1.3.1 Fineness Modulus (FM)

Fineness modulus of sand (fine aggregate) is an index number which represents the mean size of the particles in sand. It is calculated by performing sieve analysis with standard sieves. The cumulative percentage retained on each sieve is added and divided by 100 gives the value of fineness modulus [8].

The experimental work undertaken to investigate the effects of fineness modulus on concrete strength. The investigation included testing of compressive strength and workability of same concrete mix, but with different grading for the fine crushed stone used. The study revealed that the compressive strength of concrete, tested using standard cubes, increases as the fineness modulus of fine crushed stone increases, up to some point, then it decreases to leave a peak point in the compressive strength curve [9].

As fines modulus of sand changes from 2.0 to 2.5 there is an increase in 28th day compressive and flexural strength by 14% and 11.25% respectively. On the other hand by increasing fines modulus from 2.5 to 3.0, compressive and flexural strength increases by 16% and 13.1% respectively [10].

2.3 Grading of Aggregate

As much as the aggregate occupies 65 to 75 percent of the volume of concrete, the importance of having information on its physical and chemical characteristics cannot be over emphasized. In order to calculate the proportions of the different ingredients and produce concrete of desired properties, it is important and indeed required to determine the characteristics of the aggregate gradation. The grading or particle size distribution of aggregate is determined by a sieve analysis. Table 2.1 [5] gives standard series of sieves of square openings which are used in the sieve analysis of fine and coarse aggregates.

Table 2.1 Standard Sieve Sizes and Square Openings

For Fine Aggregate			For Coarse Aggregate		
ES Series	ASTM Series		ES Series	ASTM Series	
Sieve Size & clear opening	Sieve Size	Clear Opening	Sieve Size & clear opening	Sieve Size	Clear Opening
9.5 mm	3/8 in	0 .375 in	75 mm	3 in	3 in
4.75 mm	No 4	0 .187 in	63 mm	2 in	2 in
2.36 mm	No 8	0 .0937 in	37.5 mm	1 1/2 in	1.5 in
-	-	-	-	1 in	1 in
1.18 mm	No 16	0 .0469 in	19 mm	3/4 in	0.75 in
600 μm	No 30	0 .0232 in	13.2 mm	1/2 in	0.5 in
300 μm	No 50	0 .0117 in	9.5 mm	3/8 in	0.375 in
150 μm	No 100	0 .0059 in	4.75 mm	No 4	0.187 in
75 μm	No 200	0.00295 in	-	-	-

A sample of aggregate for sieve analysis is first surface dried and then sieved through the series, starting with the largest. The weight retained on each sieve is recorded and the percentage computed. The summation of the cumulative percentage of the material retained on the sieves (not including the intermediate sieves) divided by 100 is called the fineness modulus. It is used as an index to the fineness or coarseness and uniformity of aggregate supplied.

Hence aggregate is graded so as to have different sizes of particles, from the required largest size to the very fine. The use of a well graded mixture of aggregates results in improved workability of the concrete and economy of the cement since such aggregate has a decreased amount of voids between the particles and consequently requires less cement paste. For mixes of given consistence and cement content, a well-graded aggregate produces a stronger concrete than a poorly graded one because less water is required to give suitable workability.

2.3.1 Grading Requirements for Concrete Fine Aggregates

Fine aggregate should consist of natural sand obtained from the natural disintegration of rocks or sand obtained from crushed stones whereas coarse aggregate should be gravel, crushed gravel or crushed stone. The grading or particle size distribution of fine aggregate should be within limits specified in Table 2.2[5]. In addition, according to the same standard, the fineness modulus should not be less than 2.0 or more than 3.5 with a tolerance of ± 0.2.

Table 2.2 Grading Requirement for Fine Aggregate

Sieve Size (ES)	ASTM Designation	Percentage Passing
9.5 mm	3/8 in	100
4.75 mm	No 4	95-100
2.36 mm	No 8	80-100
1.18 mm	No 16	50-85
600 μm	No 30	25-60
300 μm	No 50	10-30
150 μm	No 100	2-10

2.4 Specific Gravity

The specific gravity of a substance is the ratio between the weight of the substance and that of the same volume of water. This definition assumes that the substance is solid throughout. If a section is cut through any aggregate and the surface magnified, it will be seen that it contains pores, both permeable and impermeable. Hence applied to aggregates, the term specific gravity has to be carefully defined. In fact, in concrete technology distinction is made between absolute specific gravity, apparent specific gravity and bulk specific gravity.

- Absolute Specific Gravity: defined as the ratio of the mass of a unit volume of a material (without pores) to the mass of the same volume of gas-free distilled water.

- Apparent Specific Gravity: is the ratio of the weight in air of a material of given volume (solid matter plus impermeable pores or voids) to the weight in air of an equal volume of distilled water.
- Bulk Specific Gravity: is defined as the ratio of the weight in air of a given volume of a permeable material (including both its permeable and impermeable voids) to the weight in air of an equal volume of water. In concrete mix calculations, what is necessary to know is the space occupied by the aggregate particles within the relatively thick cement paste regardless of whether or not pores or voids exist within the particles.
- Bulk Specific Gravity (Saturated Surface Dry Basis): defined as the ratio of the weight in air of a permeable material in a saturated surface dry condition to the weight in air of an equal volume of water. In the computation of quantities for concrete mixes, it is the specific gravity of the saturated surface-dry aggregates that is always used [11].

2.5 Bulk Density and Voids

Bulk Density measures the weight of the aggregate that fills a container of unit volume part of which is void because of the loose packing of the particles. The bulk density is used to convert quantities by weight to quantities by volume for batching concrete. The bulk density of an aggregate is affected by several factors including the degree of compaction applied when filling the container and the amount of moisture present in the case of fine aggregate. It is therefore important to know the conditions under which the aggregate is measured:

- Loose or compact and
- Dry, damp

In general, for comparison of different aggregates and calculation of mix quantities the standard conditions are dry and compact (rodded). However, for scheduling volumetric batch quantities, the unit weight in the loose, damp state should also be known. The unit weight of some natural aggregates specified in Table 2.3[5].

Table 2.3 General range in unit weight of some natural aggregates

Material	Kg/m^3
Sand (dry)	1520-1680
Gravel	1280-1440
Crushed Stone	1250-1400

The difference between the solid unit weight and the bulk density indicate the amount of voids between the particles.

2.6 Porosity, Absorption and Surface Moisture

The Porosity of aggregate is important since it affects its bulk specific gravity, permeability and absorption which in turn affect the properties of the resulting concrete.

Some of the pores are wholly within the solid, others are on the surface. Unless their openings are very wide, also the surface pores are considered impermeable to cement paste because of its viscosity. Hence, the gross volume of the aggregate particle, including the surface pores of narrow opening, is considered solid for the purpose of calculating the aggregate content in concrete.

As regards moisture content, the various states in which an aggregate may exist are:

- Oven-dry – completely dry
- Air-dry – dry at the surface, some internal moisture, but less than the amount required to saturate the particle.
- Saturated Surface –dry idealized condition, no free moisture on the particle, but all voids within the particle filled with water.
- Damp or wet- saturated and with free or surface moisture on its surface.

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 exceeds 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. The surface or free moisture content is generally given in terms of percent of the saturated surface dry aggregate weight.

The absorption capacity is a measure of the porosity of an aggregate. In some cases it is slightly affected by the size of the aggregate, becoming higher for the bigger aggregate. Approximate values of the absorption capacity of some types of aggregate are given in Table 2.4 [5].

Table 2.4 Approximate absorption capacities of some types of stone used for aggregate.

Material	Absorption Capacity % by Weight
Sand	0-2
Gravel	0.5-1
Basalt	0-0.5
Granite	0-0.5
Limestone (firm)	0.5-1
Sand stone	2-7
Trap Rock	0-0.5

In calculating or measuring quantities for concrete mix it is important to know the state at which the aggregate is used. If it is dry, some of the mixing water will be absorbed. If it is wet, the free moisture will become a part of the mixing water. Hence adjustments on the quantities of the materials have to be made based on the saturated surface – dry condition of the aggregate since at this state the aggregate will neither absorb nor contribute water to the mix.

2.7 Fresh Concrete

As explained earlier, concrete is made by mixing coarse and fine aggregates, cement as a dry powder and water. At times, admixtures are also added. A chemical reaction or hydration process takes place between the cement and water resulting in the formation of new compounds which bind the aggregates together into a coherent solid mass. The cement paste remains in a fresh or plastic state for few hours after mixing enabling the concrete to be transported, compacted and molded into the desired shape. The chemical reaction between the cement and water or the hydration process continues and in due time the cement paste, hence the concrete, stiffens into the final hardened state. In the fresh state, concrete may have many of the attributes of denser liquid or plastic solid whilst in the hardened state it exhibits rheological properties which have been described as viscoelastic.

2.7.1 Properties of fresh Concrete

When concrete was adopted as a binding material decades ago, the practice was to place it in relatively thin layers, with a consistence resembling that of moist earth. It was then compacted at the expense of a hard labor. As plain concrete, it first found use in heavy structures with sizable dimensions. But later on, with the introduction of reinforced concrete came the diversified uses of concrete in the building industry and thus the need for concrete of consistence other than that of moist earth.

In the fresh (as well as the hardened) mixture we have two major components:

- The cement paste – consisting of water and cement, and
- The aggregates

When preparing a concrete mix, once main concern is to produce a concrete having the required properties which make it easy to handle when fresh, and serve the purpose it is intended for when hardened, such fresh concrete is said to be workable.

2.7.1.1 Workability

In the freshly mixed plastic concrete the aggregate and cement particles are temporarily suspended in water. This separation of the particles and the lubrication effect of the water layers, together with the inter-particle forces among the finest particles, make the fresh mixture plastic and possible to place, compact and mold in any shape and hence workable.

Workability of concrete is defined as " the combined effect of those properties of fresh concrete that determine the amount of internal work required for placement and compaction, and that determine the resistance to segregation" [12].

Workability comprises at least three separate properties as follows:

- Compact ability or the ease with which the concrete can be compacted and the air voids be removed,

- Mobility or the ease with which concrete can flow into molds, around reinforcing steel and be remolded (i.e. property which is inversely proportional to the internal resistance of the mix to deformation), and
- Stability or the ability of concrete to remain a stable coherent homogeneous mass during handling and vibration without the constituents segregating.

Whatever the definition, it must be understood that workability is a relative property which should be seen in a relation to the equipment used for mixing, the method of transporting, placing consolidating, and the size and shape of the mass to be formed. A concrete that is workable under some conditions may not be workable under some other conditions.

2.7.1.2 Consistence

Consistence is the term used to denote the degree of wetness or fluidity of concrete. Although it doesn't mean the same thing it is closely related to, and is a major factor of workability. By definition it is "That property of a material by which it resists a permanent change of shape and it is defined by the complete flow-force relation." [13].

It is generally agreed that workability and consistence are not only the most important rheological properties of fresh concrete, but also important factors as far as the finished and hardened product is concerned, since concrete must have a workability such that compaction to maximum density is possible with a reasonable amount of work or with the amount that one is prepared to put in under given conditions.

Experience has shown that wet concretes are more workable than dry (stiff) concretes, but concretes of the same wetness (consistence) may differ in workability. The degree of wetness of a concrete mixture may be classified and described as stiff, plastic, and flowing.

Usually a workable concrete is plastic, although under certain conditions of placement stiff concretes are usable and therefore, considered workable.

2.7.1.3 Factors that affect workability and consistence

Workability and consistence of fresh concrete are principally affected by the materials that constitute in concrete. Summarizing the basic influences of the constituent materials of the different phases on the workability and consistence of concrete, Ma Millan F.R. [14] wrote as follows:

The factors governing the plasticity of a concrete mixture are:

- Relative quantities of cement paste and aggregates.
- Plasticity of the cement paste.
- Grading of aggregates.
- Shape and surface characteristics of aggregate particles

He further adds, for any given paste, that is, a quantity of cement with its definite proportion of water, decreasing the amount of paste with respect to the quantity of aggregate stiffens the mixture, and increasing the amount of paste renders the mix more fluid. If the quantity of paste is reduced to the point where there is not enough to fill the spaces and actually float the aggregate particles, the mix will become granular or harsh and will be impossible of proper placement.

Similarly, for a given quantity of paste and aggregate the plasticity of the mix will depend upon the relative quantities of cement and water in the paste. A paste that is high in cement and low in water content will itself be stiff and cannot carry much aggregate without becoming so stiff as to be wholly unplaceable. On the other hand, if the cement content of the paste is low and the water content high, the paste may be so thin and watery that it will be unable to hold the aggregates in the cohesive mass which is the very embodiment of plasticity.

The grading of the aggregates affects the plasticity of the concrete:

- By affecting the quantity of paste necessary to fill the spaces thoroughly and surround the aggregate particles completely, and
- By affecting the resistance which is offered to the mobility of the mass through the varying combinations of size.

As in the case of grading, the shape and surface characteristics of particles affect the plasticity of the mix through their effect on the amount of paste required and on the friction between the particles as the concrete is molded. Angular particles or those with rough surfaces require a greater amount of paste for the same mobility of mass than is necessary for well-rounded particles or those with smooth and slippery faces, other conditions remaining the same.

Initially, as indicated before, fresh cement paste is nothing else but a coarse suspension of granular solid particles dispersed in a continuous fluid medium.

The properties of fresh cement paste are dependent on some factors which has found out by investigators include:

- The initial volume fraction of cement particles as given by the water/cement ratio
- The chemical composition of the cement
- The particle size and size distribution of the cement
- The degree of hydration
- The temperature
- The mixing conditions

2.7.2 Batching and mixing fresh concrete

After the strength and quality i.e., the type of concrete needed for a job has been decided upon and the mix quantities determined by calculation, all materials should be accurately measured.

There are two methods of batching: the weight batching and the volume batching. Weight batching preferred over volume batching specially on important jobs. This is because of the fact that the quantity of solid materials in a container very much depends on its degree of compaction i.e. on the closeness with which the material packs. If the material packs closely with few air voids, the solid volume of materials is greater than if the material is packed loosely. This is the more so if the material is made of fine particles.

Concrete is either mixed by hand or by machine. Machine mixing obviously gives better and uniform mixes than the method described above, and because of these reasons, it is generally preferred and recommended.

Whether mixing is done by hand or by mixer the aim should be to bring all materials into a homogeneous mixture of uniform consistence. Mixing should continue until the sand particles and all the coarse aggregate are completely coated with thoroughly mixed paste and mortar respectively.

The minimum mixing time recommended by the U.S. Bureau of Reclamation [15], after all ingredients, except the last of the water, are in the mixer, is as follows:

Table 2.5 the minimum mixing time recommended by the U.S. Bureau.

Capacity of mixer (m^3)	Time of mixing minutes
1.5	1.5
2.3	2.2
3.-	2.5
4.5	3.-

2.7.2.1 Mix Design Process

The proportioning of concrete mixtures, more commonly referred to as mix design, is a process that includes selection of the suitable ingredients and determining their relative quantities.

The cost of concrete is made up of the costs of materials, labor, and equipment. However, except for some special concretes, the costs of labor and equipment are largely independent of the type and quality of concrete produced.

A properly designed mix must be capable of being placed and compacted properly with the equipment available. Finishability must be adequate, and segregation and bleeding should be minimized. The Concrete should be supplied at the minimum workability that will permit adequate placement.

The nominal maximum size of aggregate should be the largest that is economically available and consistent with dimensions of the structure. Hence, concretes with the larger sized aggregates require less mortar per unit volume of concrete. Table 2.6 [16] shows Volume of coarse aggregate per unit of volume of concrete.

Table 2.6 Volume of Coarse Aggregate per unit of volume of Concrete.

Nominal maximum size of aggregate, mm	Volume of dry rodded coarse aggregate per unit volume of concrete for different fineness moduli of fine aggregate.			
	2.4	2.6	2.8	3.0
9.5	0.5	0.48	0.46	0.44
12.5	0.59	0.57	0.55	0.53
19	0.66	0.64	0.62	0.6
25	0.71	0.69	0.67	0.65
37.5	0.75	0.73	0.71	0.69
50	0.78	0.76	0.74	0.72
75	0.82	0.8	0.78	0.76
150	0.87	0.85	0.83	0.81

2.7.3 Handling, Placing and Compacting Concrete.

In order to secure good hardened concrete, certain fundamental principles should be borne in mind in handling it when fresh. The best concrete mix can be easily damaged when a little mistake is made on the way from the mixing place to the forms. Therefore, each step in handling and transporting should be carefully controlled. Segregation i.e. separation of the coarse aggregate from the mortar or of water from the other ingredients, should be prevented. The equipment and method of handling and transporting concrete should be selected according to placing conditions.

Concrete is a plastic material when fresh hence it needs forms or molds until it sets and hardens. The forms are generally made of either timber or steel. Before placing concrete the forms and subgrade should be cleaned and moistened thoroughly specially in hot weather. In order to prevent concrete from adhering to the surface, forms should be thoroughly oiled.

Compaction is one of the last, but important steps in concrete making, because the density, strength and durability of the concrete depend so much on it. The object of compaction is to illuminate air holes and to achieve maximum density which leads to higher strength. It is also ensures an intimate contact between the constituent materials, and embedded parts.

Compaction is done by hand or vibrator. When compacting by hand, the concrete should be rodded, tamped and spaded so as to make it settle thoroughly everywhere in the forms and produce a dense mass. The working of the concrete next to the forms is very important since it forces the large stone particles away from the face into the mass of the concrete and ensure modern compaction is done by vibration. The use of vibration, which enables stiffer mixes to be compacted, leads to two possible advantages compared with hand compaction: either a much stronger concrete can be produced for a given cement content by reducing the water content and therefore the water cement ratio, or the same strength concrete can be produced with less cement.

2.7.4 Tests on Fresh Concrete

As pointed out earlier, workability of fresh concrete is a relative property. A concrete workable under one condition might not be workable under another. To date there is unfortunately no direct test method to measure the workability and consistence of fresh concrete. There are, however, approximate methods which give information within a range of consistence and workability good enough for practical purpose.

2.7.4.1 The Slump Test

The slump test is perhaps the most widely used method of checking the consistence of concrete. Used at the construction site, it provides useful information on the uniformity in the day-to-day or even hour-to-hour production of concrete. Table 2.7 [16] shows recommended slump values for various types of construction.

Table 2.7 Recommended Slump values for various types of construction

Types of construction	Slump, mm	
	Minimum	Maximum
Reinforced foundation, walls & footings	25	75
Plain footings, caissons & substructure walls	25	75
Beams and Reinforced walls	25	100
Building Columns	25	100
Pavements and Slabs	25	75
Mass Concrete	25	75

The method as devised in the late twenties in America, was a simple frustum of cone. There are some light differences in the details of both the dimensions of the apparatus and the details of procedures used in different countries. The frustum of a cone should be 305 mm high 203 and 102 mm diameter at the bottom and top respectively [17]. After being moistened, it is placed on a smooth surface with the smaller opening at the top, and filled with the concrete sample in three layers, each approximately one third of the volume of the cone. Each layer is temped 25 times with a standard straight tamping rod 16 mm in diameter while the mold is held firmly against its base. Immediately after filling, the cone is slowly lifted leaving the unsupported concrete to slump. The consistence is measured in terms of the amount it has slumped in centimeters. Three types of results could be obtained:

- The sample could slump evenly all around in which case it is said to be a true slump.
- Part of the top cones might shear off and slide down an inclined plane giving a shear slump, and
- The cone could completely collapse

The first type of slump indicates a well-proportioned concrete whereas the second, or shear slump, occurs usually with harsh mixes with lack of cohesion. Mixes of stiff consistence have a zero slump.

The loss of workability of fresh concrete with time depends in turn on factors such as the richness of the mix, the type of cement, the temperature of the concrete, and the initial workability.

2.8 Curing of Concrete

Moisture is necessary for the proper hardening of concrete because the chemical action which results in the setting and hardening of the paste takes place only in the presence of water. It is true that the amount of water normally used at the time of mixing is adequate for this purpose, however, the loss from evaporation from the time the concrete is mixed and placed is usually so rapid that there may not be enough of it left for full hydration and hardening. Excessive loss of water due to evaporation may cause the hydration process to stop all together with a consequent reduced strength development. In addition, if concrete dries out too quickly by exposure to sun and wind, it will shrink. This early and usually rapid shrinkage will result in tensile stresses which will lead to surface cracks.

It is important therefore that fresh concrete be kept moist for several days after placing. This process, known as curing should begin soon after the concrete is set and continue preferably for a number of days. There are different methods of curing concrete including sprinkling, ponding with water, or covering with continuously wetted sand.

From the above, the purpose of curing can be summarized as follows:

- Curing is to prevent formation of surface cracks due to rapid loss of water while the concrete is fresh and weak.
- To assure attainment of strength by providing enough moisture for the hydration of the cement grains throughout the concrete. Curing is most important in hot climates.

2.9 Shrinkage of Concrete

When stored in an unsaturated air, concrete losses part of its water content through evaporation. The withdrawal of water starts while the concrete is still in a fresh or plastic state and continues for several days and months after the concrete has hardened. The corresponding dimensional changes are known as plastic and drying shrinkage.

Two types of drying shrinkage are generally observed. When first dried, concrete undergoes shrinkage, known as initial drying shrinkage and is partly irreversible. On subsequent wetting and drying it shows approximately reversible expansion and contraction, usually called reversible moisture movement.

Initial drying shrinkage of concrete is affected by different factors such as:

- Unit water content,
- Cement content and quantity of the paste,
- Composition and fineness of the cement,
- Type and grading of aggregate,
- Size and shape of the concrete mass, and
- Curing condition.

Concretes with higher paste concrete have generally greater shrinkage values since high paste content is the result of larger amount of cement content. It is also understood that cement pastes made with fine cement exhibit slightly greater shrinkage values [18].

The mineral composition, grading and mechanical properties of aggregates constitute one of the few if not the most important factors on the shrinkage of concrete. The mineral composition of aggregates is important because under comparable conditions, minerals behave differently when alternately wetted and dried.

The maximum size and grading of aggregates influence the magnitude of shrinkage indirectly. Well graded aggregates with a large maximum size have a low void space and permit the use of a leaner mix, larger maximum size aggregate also allows lower water content, consequently both effects result in a lower shrinkage.

2.10 Summary of Literature Review

From the above review, the quality of good concrete is dependent mainly on the quality of its constituent materials. The strength characteristics of concrete also depend upon the properties of constituent material and their combined action. It is a known fact that concrete making aggregates constitute the lion share of the total volume of concrete. In order to calculate the proportions of the different ingredients and produce concrete of desired properties, it is important and indeed required to determine the characteristics of the aggregate gradation

The strength of concrete is affected by a number of factors. The most important factors that affects concrete strength is the fine aggregate. For this purpose we must calculate the fineness modulus of sand (fine aggregate), which is an index number which represents the mean size of the particles in sand. It is calculated by performing sieve analysis with standard sieves.

Fine aggregate should consist of natural sand obtained from the natural disintegration of rocks or sand obtained from crushed stones whereas coarse aggregate should be gravel, crushed gravel or crushed stone. The grading or particle size distribution of fine aggregate should be within limits specified in ASTM. In addition, according to the same standard, the fineness modulus should not be less than 2.0 or more than 3.5 with a tolerance of ± 0.2.

CHAPTER THREE

MATERIAL PROPERTIES AND EXPERMENTAL PROGRAM

3.1 Material Properties

3.1.1Aggregates

The relevant tests were made to identify the properties of the aggregates which are used for this research. After that, corrective measures were taken in advance before proceeding to the mix proportioning, like blending the aggregates in order to meet the grading requirement, washing the aggregates in order to meet the standard for the silt content. In general, aggregates should be hard and strong, free of undesirable impurities, and chemically stable. Soft, porous rock can limit strength and wear resistance; it may also break down during mixing and adversely affect workability by increasing the amount of fines. Aggregates should also be free from impurities: silt, clay, dirt or organic matter.

3.1.1.1 Properties of Fine Aggregate

CR sand was totally used in all concrete mixes as fine aggregate. The CR sand used for testing all concrete samples was provided by Teklehaymanot crusher quarry as a waste of producing gravel (Coarse CR).The CR sand used for each mix was dry and stored in the same area. In order to investigate its properties for the required application different tests were carried out which include: silt content, sieve analysis and fineness modules (F.M), specific gravity, absorption capacity, moisture content, silt content and unit weight.

3.1.1.1.1 Silt Content

The material in fine aggregates which is finer than 75µm is generally regarded as silt [19]. This silt in the CR 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. From the silt content test performed on the CR sand, it was found that the original silt content was 5.8%.

3.1.1.1.2 Sieve Analysis and Fineness Modules (FM)

This is a procedure for the determination of the particle size distribution of the aggregate. It is also used to determine the fineness modulus, an index to the fineness, coarseness and uniformity of aggregates. These properties of the aggregate greatly affect the property of the concrete. Different grading of CR sand used in each concrete mix. The fineness modulus of the fine CR sand from the source was founded 3.23.

Fine CR sand with different fineness modulus was prepared and used for each concrete mix. The required fineness modulus was achieved by sieving the CR sand using Hand sieving process to maintain the required quantity of retained CR sand size on each standard sieve. Fineness modulus of 2.2, 2.5, 2.8, 3.0 and 3.2 were prepared for the concrete mixes. Table (3.1) through (3.5) shows the different grading of fine CR sand used to achieve the different fineness modulus used in each concrete mix. All used fine CR sand grading matches the ASTM grading requirements of fine aggregate.

Table 3.1 Grading of CR Sand with FM of 2.2

sieve size(mm)	Cumm. ASTM % of passing range (lower bound)	Cumm. ASTM % of passing range (upper bound)	cumm.%retained	Cumm.% passing of CR Sand
4.75	95	100	0.6	99.4
2.36	80	100	4.9	95.1
1.18	50	85	18.1	81.9
0.6	25	60	40.0	60
0.3	10	30	70.3	29.7
0.15	2	10	90.7	9.3
F.M			**2.2**	

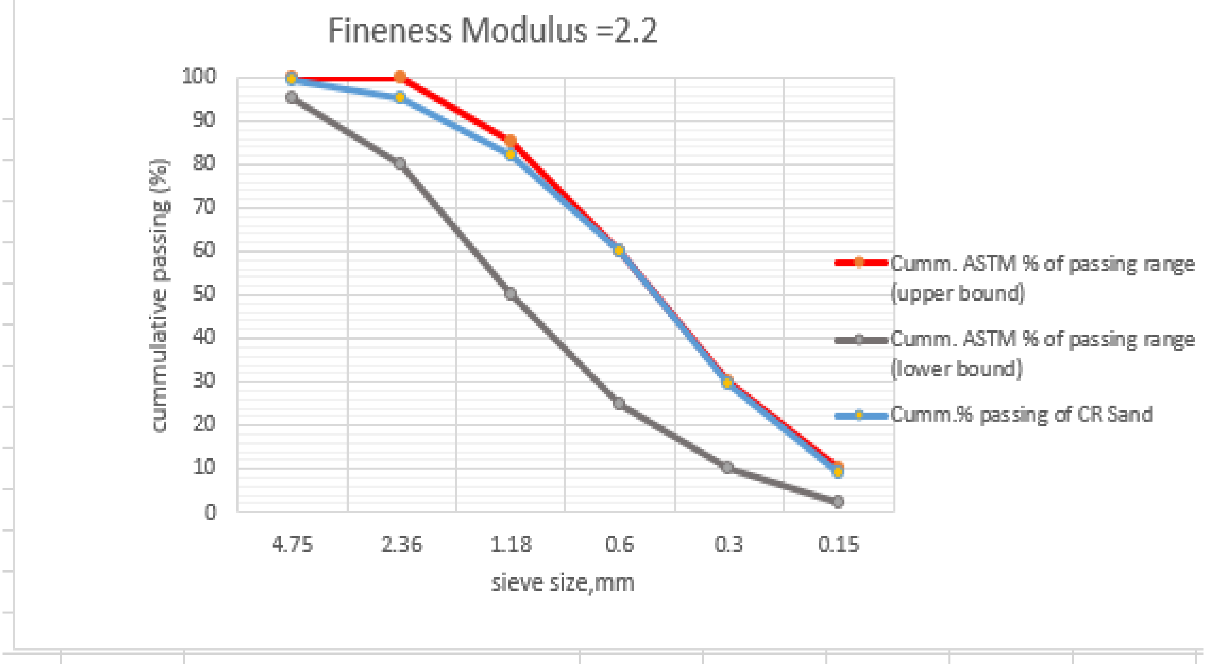


Figure 3.1 Graph for grain size distribution of CR sand for F.M of 2.2

Table 3.2 Grading of CR Sand with FM of 2.5

sieve size(mm)	Cumm. ASTM % of passing range (lower bound)	Cumm. ASTM % of passing range (upper bound)	cumm.%retained	Cumm.% passing of CR Sand
4.75	95	100	1.9	98.1
2.36	80	100	9.4	90.6
1.18	50	85	32.1	67.9
0.6	25	60	49.1	50.9
0.3	10	30	70.2	29.8
0.15	2	10	90.0	10.0
F.M			**2.5**	

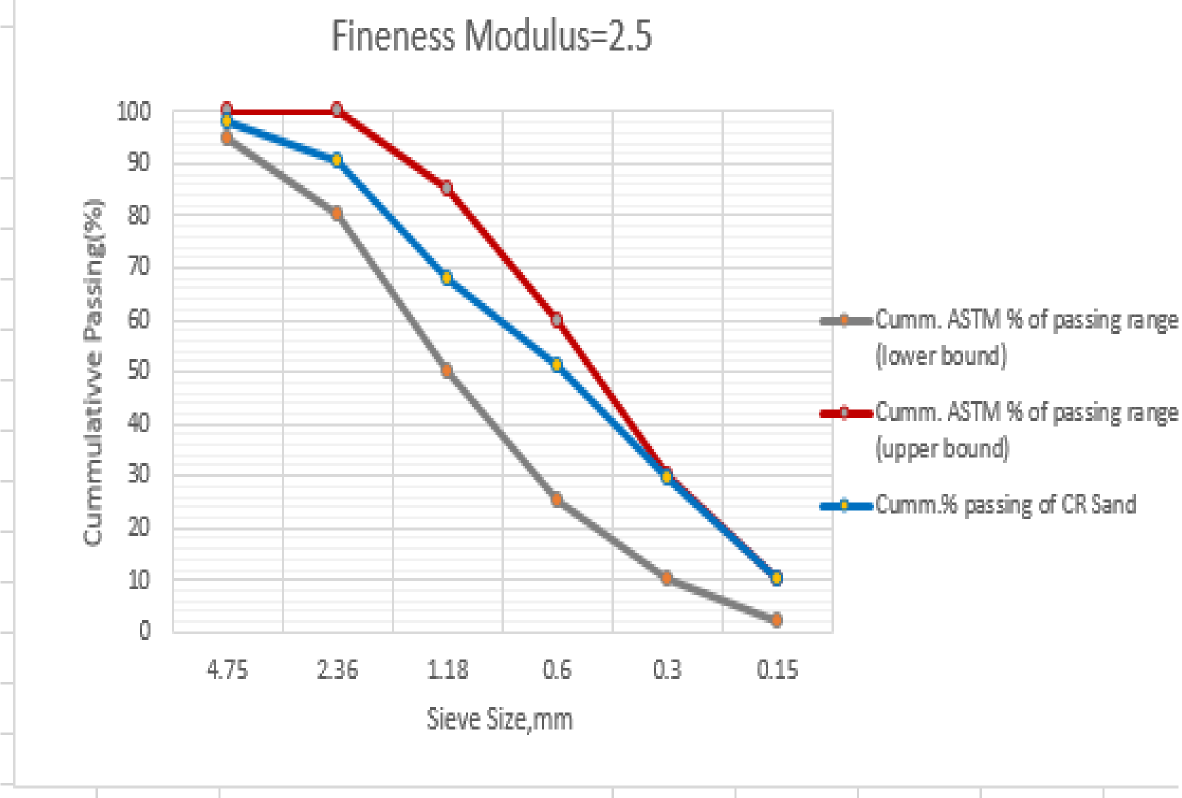


Figure 3.2 Graph for grain size distribution of CR sand for F.M of 2.5

Table 3.3 Grading of CR Sand with FM of 2.8

sieve size(mm)	Cumm. ASTM % of passing range (lower bound)	Cumm. ASTM % of passing range (upper bound)	cumm.%retained	Cumm.% passing of CR Sand
4.75	95	100	2.8	97.2
2.36	80	100	16.0	84.0
1.18	50	85	44.3	55.7
0.6	25	60	60.2	39.8
0.3	10	30	71.3	28.7
0.15	2	10	90.0	10.0
F.M			**2.8**	

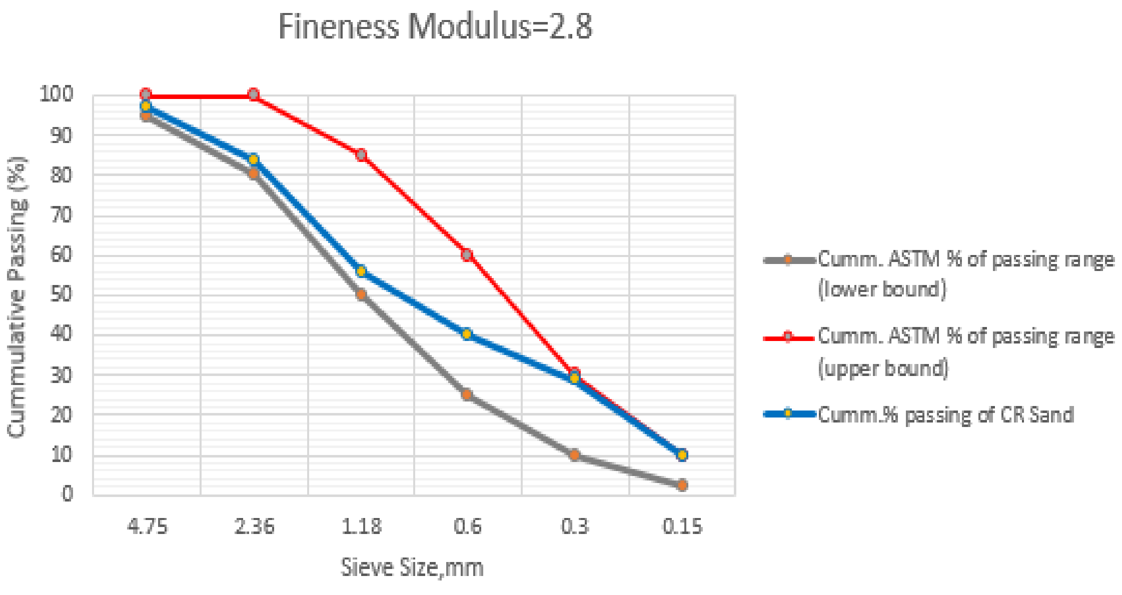


Figure 3.3 Graph for grain size distribution of CR sand for F.M of 2.8

Table 3.4 Grading of CR Sand with FM of 3.0

sieve size(mm)	Cumm. ASTM % of passing range (lower bound)	Cumm. ASTM % of passing range (upper bound)	cumm.%retained	Cumm.% passing of CR Sand
4.75	95	100	3.4	96.6
2.36	80	100	17.8	82.2
1.18	50	85	48.0	52.0
0.6	25	60	65.0	35.0
0.3	10	30	80.3	19.7
0.15	2	10	90.0	10.0
F.M			**3.0**	

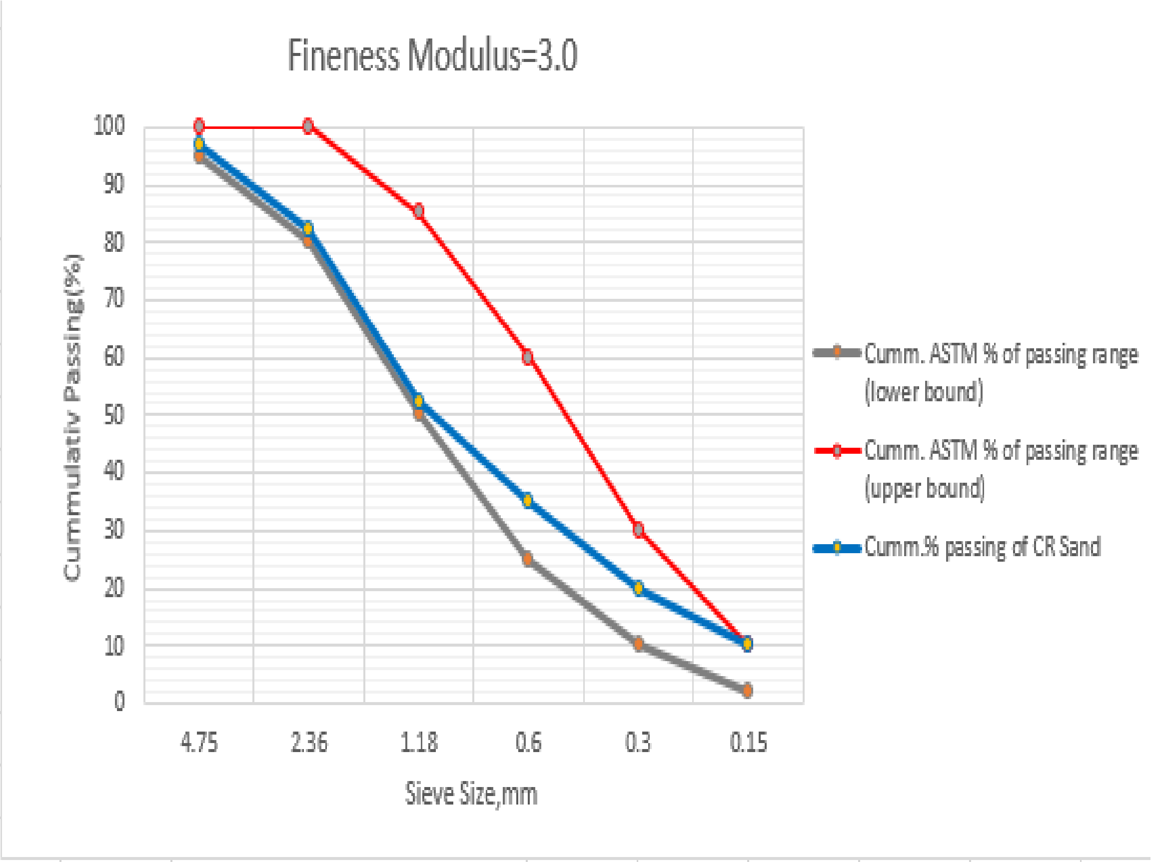


Figure 3.4 Graph for grain size distribution of CR sand for F.M of 3.0

Table 3.5 Grading of CR Sand with FM of 3.2

sieve size(mm)	Cumm. ASTM % of passing range (lower bound)	Cumm. ASTM % of passing range (upper bound)	cumm.%retained	Cumm.% passing of CR Sand
4.75	95	100	4.7	95.3
2.36	80	100	19.8	80.2
1.18	50	85	50.0	50.0
0.6	25	60	70.8	29.2
0.3	5	30	86.8	13.2
0.15	0	10	90.4	9.6
F.M			**3.2**	

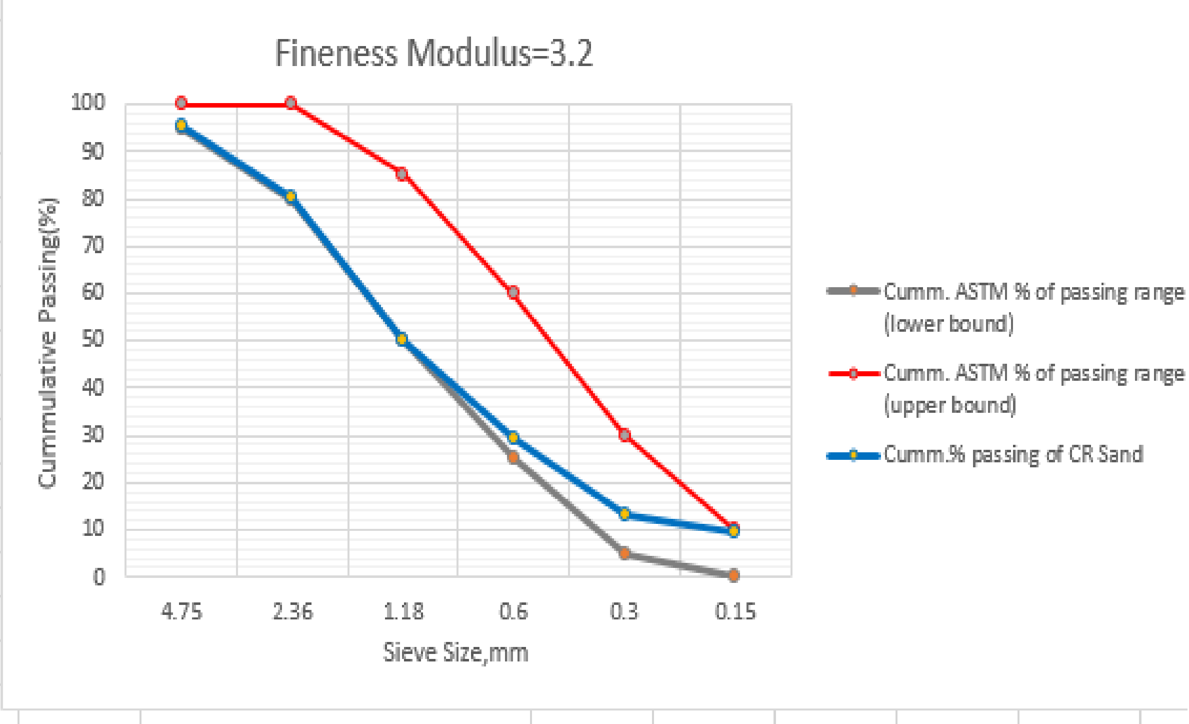


Figure 3.5 Graph for grain size distribution of CR sand for F.M of 3.2

Figure 3.6 shows Summary graph for grain size distribution of CR sand F.M from 2.2 to 3.2.

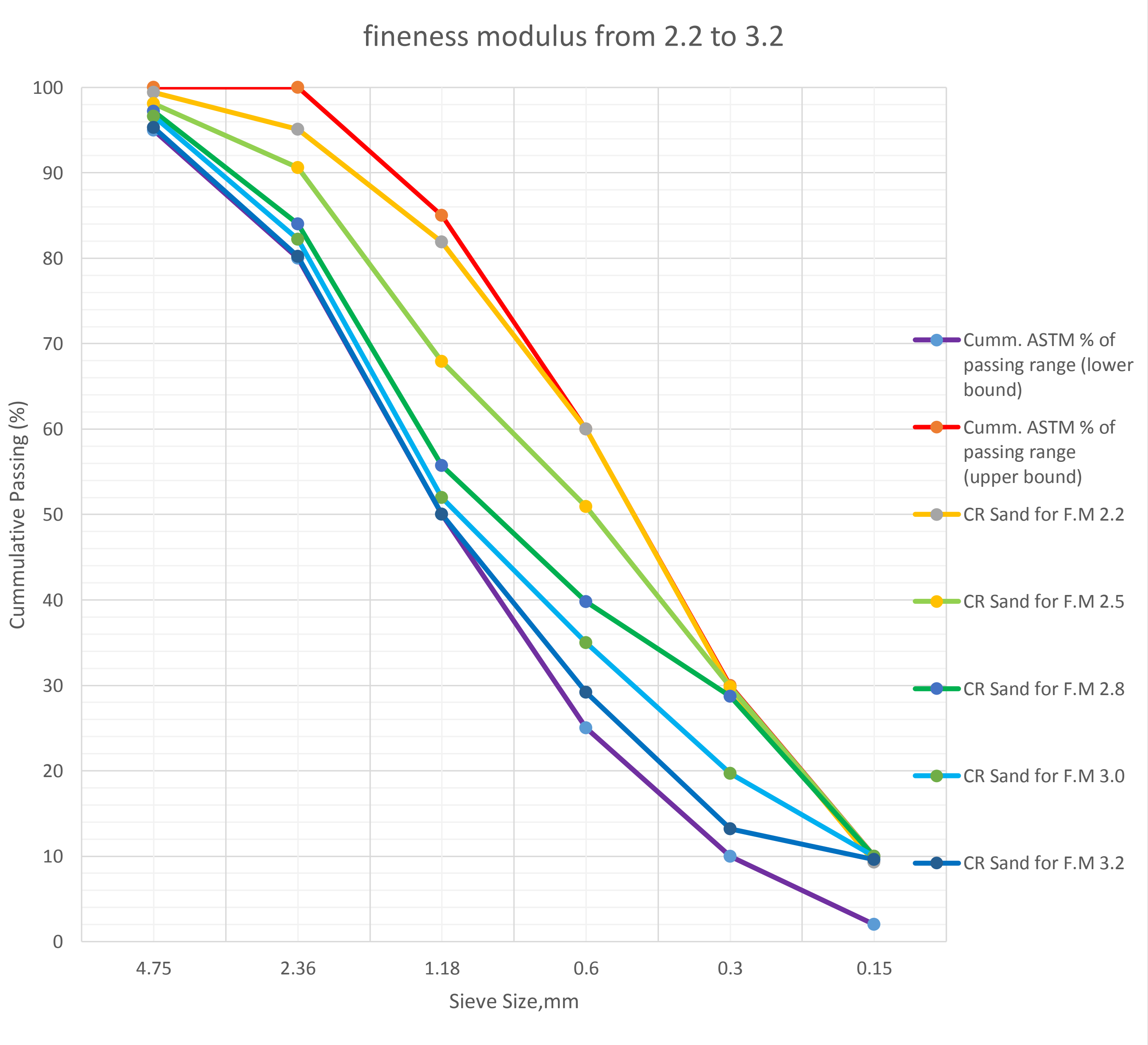


Figure 3.6 Summary graph for grain size distribution of CR sand F.M from 2.2 to 3.2

3.1.1.1.3 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 absorption capacity is a measure of the porosity of an aggregate. It represents the total water contained in the aggregate in the saturated surface –dry condition. The following results are found for the fine aggregate:

Bulk specific gravity = 2.79

Bulk specific gravity (SSD basis) = 2.83

Apparent specific gravity = 2.91

Absorption capacity = 1.52%

3.1.1.1.4 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 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.

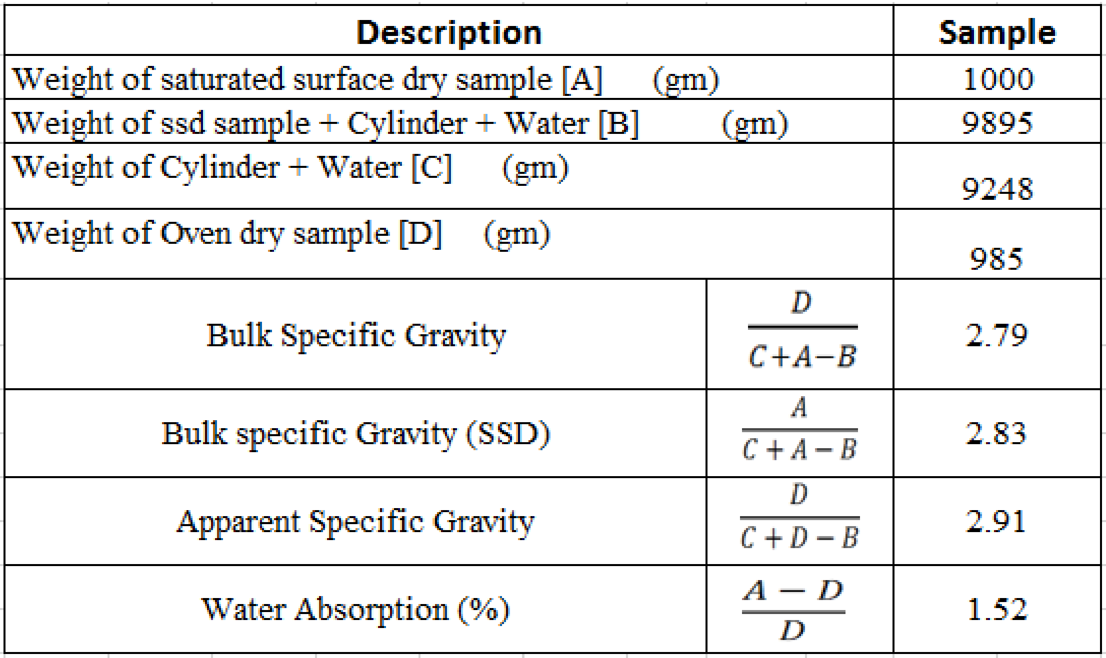
The moisture content of fine aggregates was determined by oven drying a sample of fine aggregate (500gm) in an oven at a temperature of 110^{0}C for 24 hours and dividing the weight difference by the oven dry weight [20]. The moisture content found was 2.46 %.

3.1.1.1.5 Unit Weight

Unit weight can be defined as the weight of a given volume of graded aggregate. It is thus a density measurement and is also known as bulk density. But this alternative term is similar to bulk specific gravity, which is quite a different quantity, and perhaps is not a good choice.

The unit weight effectively measures the volume that the graded aggregate will occupy in concrete and includes both the solid aggregate particles and the voids between them. The unit weight is simply measured by filling a container of known volume and weighing it. Clearly, however, the degree of compaction will change the amount of void space, and hence the value of the unit weight. Since the weight of the aggregate is dependent on the moisture content of the aggregate, constant moisture content is required. Oven dried aggregate sample is used in this test [6]. The unit weight of the fine aggregate sample used was found to be 1.553 gm/cm^3. The above test results are summarized in Table 3.6 below:

Table 3.6 Summary of Test Results for Fine Aggregate



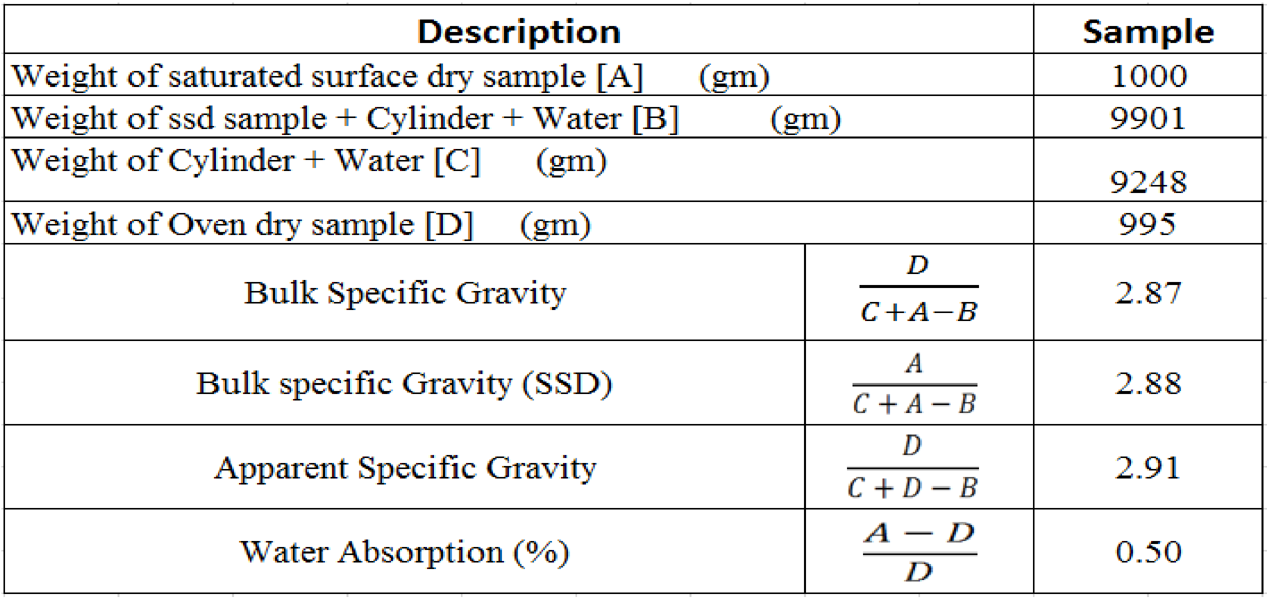
Description		Sample
Weight of saturated surface dry sample [A] (gm)		1000
Weight of ssd sample + Cylinder + Water [B] (gm)		9895
Weight of Cylinder + Water [C] (gm)		9248
Weight of Oven dry sample [D] (gm)		985
Bulk Specific Gravity	$\frac{D}{C+A-B}$	2.79
Bulk specific Gravity (SSD)	$\frac{A}{C+A-B}$	2.83
Apparent Specific Gravity	$\frac{D}{C+D-B}$	2.91
Water Absorption (%)	$\frac{A-D}{D}$	1.52

3.1.1.2 Properties of Coarse Aggregate

The coarse aggregates used for this research were from Teklehaymanot crusher which is available around Bole Lemi (6Km from Goro). Because the aggregates have been stored in the stock for a while, visual examination reveals that there is a dust film on their surface and therefore, the aggregates were washed thoroughly and dried in open air outside the laboratory. A maximum aggregate size of 25 mm was used in all the concrete mix. After washing and drying, the coarse aggregates were sieved and stored. This has minimized segregation and thus variation in gradation from mix to mix.

In a similar manner like the fine aggregate, laboratory tests were carried out to identify the physical properties of the coarse aggregate and the results are shown in Table 3.7 below and Table 3.8 shows the sieve analysis test results [21].

Table 3.7 Summary of Test Results for coarse Aggregate



Description		Sample
Weight of saturated surface dry sample [A] (gm)		1000
Weight of ssd sample + Cylinder + Water [B] (gm)		9901
Weight of Cylinder + Water [C] (gm)		9248
Weight of Oven dry sample [D] (gm)		995
Bulk Specific Gravity	$\frac{D}{C+A-B}$	2.87
Bulk specific Gravity (SSD)	$\frac{A}{C+A-B}$	2.88
Apparent Specific Gravity	$\frac{D}{C+D-B}$	2.91
Water Absorption (%)	$\frac{A-D}{D}$	0.50

Table 3.8 Sieve Analysis for Coarse Aggregate

Sieve size (mm)	Cumm. ASTM % of Passing range	Cumm. % Passing
25	95-100	95.8
19	-	74
12.5	25-60	31.2
9.5	-	20.5
4.75	0-10	5.8

3.1.2 Cement

Dangote Ordinary Portland Cement (OPC) from local markets of 42.5R grade was used.

3.1.3 Water

In this research, tap water supplied by Addis Ababa Water and Sewerage Authority found in the laboratory was used in all mixes.

3.2 Experimental Program

3.2.1 Mix Design and Trial Mix Preparation

Mix design is the process of determining the required and specified characteristics of a concrete mixture. The required or specified concrete characteristics can be fresh concrete properties, mechanical properties of the hardened concrete such as strength and durability requirements and the inclusion or exclusion of specific ingredients [22].

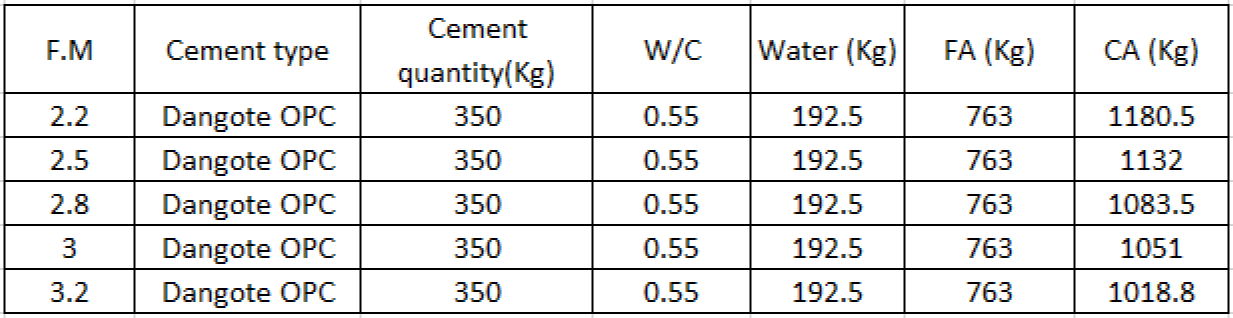
Mix proportioning on the other hand is the process of determining the quantities of concrete ingredients using local materials to achieve the specified characteristics of the concrete. According to Steven H. [22], a properly proportioned concrete mix should possess the following qualities:

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

Therefore the key for producing a strong, durable and economical concrete rests on the careful proportioning and mixing of the ingredients.

The trial mix was prepared for characteristics strength of 25MPa with water to cement ratio (w/c) of 0.55, 763Kg of CR sand, 1617Kg of CA and a cement content of 350kg for 1 m^3 by using the original FM of fine aggregate. The trial mix resulted in a slump of 71 mm and a seven day compressive strength of 25.10MPa. The slump of the concrete achieved the targeted slump which is 25-100mm [16]. The 7 day compressive strength was used to extrapolate the 28 days compressive strength. The ratio of the 28 days strength to the 7 days strength lies between 1.3 and 1.7 and it depends on the cement type and curing temperature [4]. Taking 1.5 as the extrapolation factor, the 28 days compressive strength will be around 37.65MPa which is slightly higher than the targeted value. Using Table 2.6 as a reference for extrapolation of CA volume due to the variation in fines modulus of FA the the final mix proportions for $1m^3$ of the concretes are as shown in Table 3.9.

Table 3.9 Mix Proportion for the Concrete Work



F.M	Cement type	Cement quantity(Kg)	W/C	Water (Kg)	FA (Kg)	CA (Kg)
2.2	Dangote OPC	350	0.55	192.5	763	1180.5
2.5	Dangote OPC	350	0.55	192.5	763	1132
2.8	Dangote OPC	350	0.55	192.5	763	1083.5
3	Dangote OPC	350	0.55	192.5	763	1051
3.2	Dangote OPC	350	0.55	192.5	763	1018.8

3.2.2 Preparation of Concrete Specimens and Mixing Procedure

Weight measurement was used for the preparation of the constituent. After determining the relative amount of materials to be used for the specimens, the dry aggregates and the cements were mixed for one minute. After the addition of water, all the materials were mixed for another two minutes. Immediately after mixing the concrete, the workability is measured by using a slump cone. The specimens were then placed on a firm and level surface of prepared molds (150 x 150 x 150mm) by compacting in three layers using tamping rod. After compacting, the top surface is finished using a trowel. After 24 hours the specimens were demolded from the mold and were cured in a curing pond until testing dates.

CHAPTER FOUR

TEST RESULTS AND DISCUSSION

4.1 General

The Fineness Modulus (F.M) of crushed stone used as fine aggregate has been changed to examine their effect on the workability of fresh concrete mixes, compressive strength of hardened concrete cubes and Flexural strength.

4.2 Results and Discussions on the Compressive Strength for Hardened Concrete.

The compressive strength test of concrete is the most common test type for the hardened concrete. The reasons for these are; many codes and design manuals are based on this property, many other properties of concrete depend on the compressive strength and when compared to other tests this is an easy one. Figure 4.1 below shows a compressive strength test under progress.

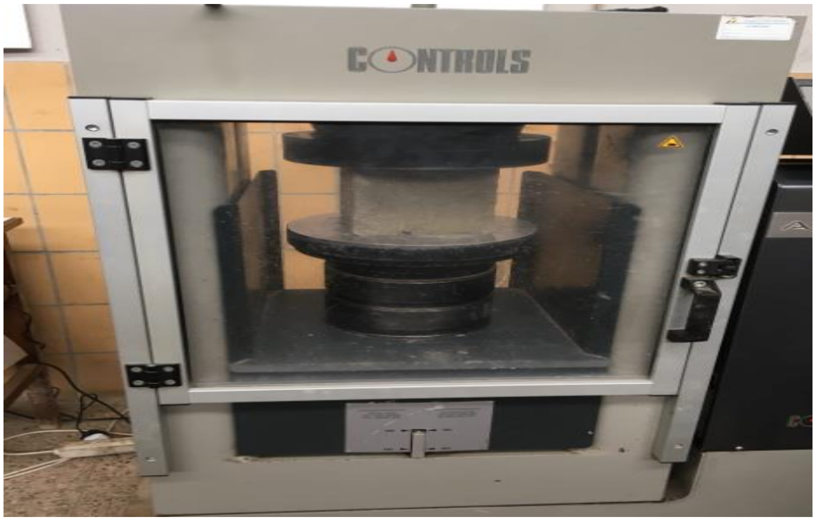


Figure 4.1 Compressive strength of concrete being tested

The compressive strength of each of the concrete is determined by testing the cubes in a compression machine. For each of the mixes the average value of three samples is taken as their compressive strength. The Specimens were tested at the age of 7, 28 and 56 days. Table 4.1 shows this compressive strength values:

Table 4.1 Average compressive strength values of concrete

F.M	Average Compressive Strength					
	7 days		28 days		56 days	
	Failure Load(KN)	Strength (Mpa)	Failure Load(KN)	Strength (Mpa)	Failure Load(KN)	Strength (Mpa)
2.2	542.5	24.11	856.6	38.07	929.3	41.3
2.5	571.5	25.4	927.2	41.21	1053.4	46.82
2.8	662.0	29.42	1003.8	44.61	1150.9	51.15
3	597.8	26.57	900.2	40.01	1012.7	45.01
3.2	511.4	22.73	838.6	37.27	927.7	41.23

In Figure (4.2) a curve for 7, 28, and 56 day compressive strength versus F.M of testing results to determine the optimum fineness modulus range for the fine crushed sand used in concrete mix in order to improve the maximum compressive strength of hardened concrete.

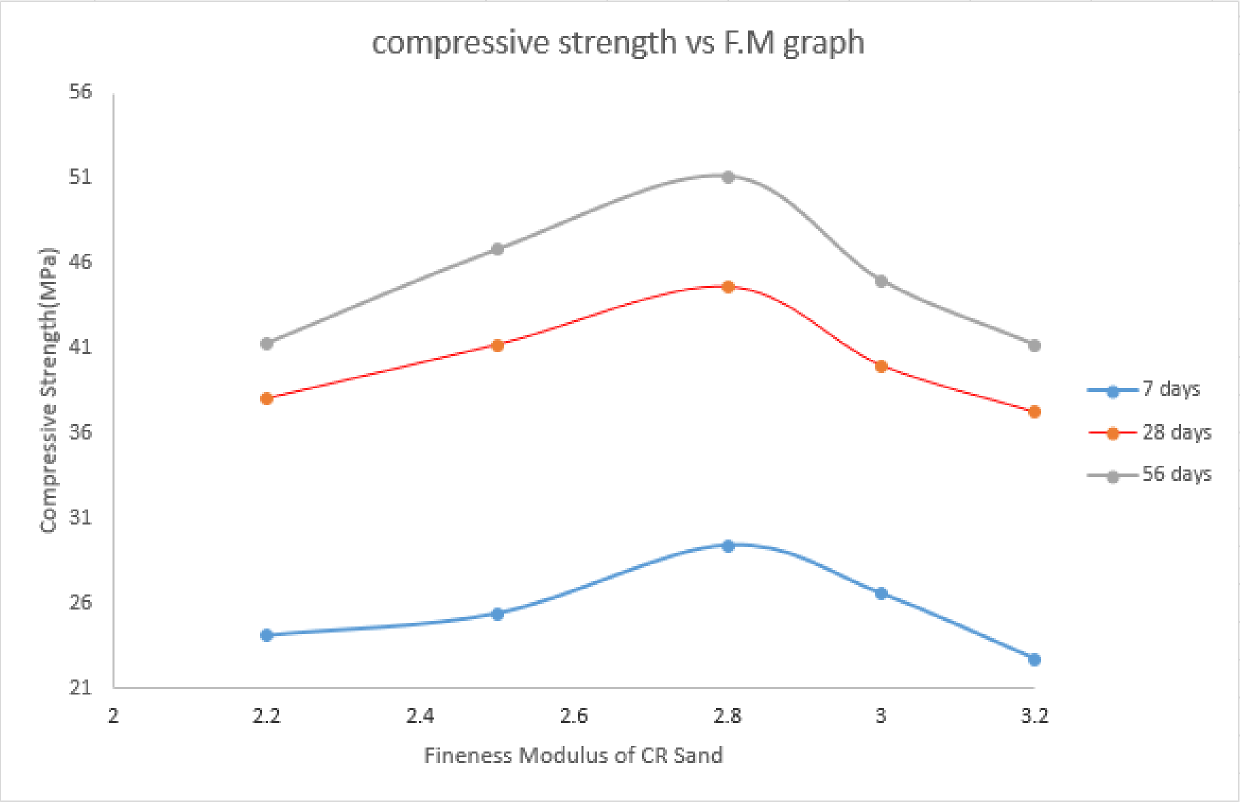


Figure 4.2 compressive strength versus F.M of the concrete

From the above figure the optimum Fineness Modulus range of the fine crushed sand to get the maximum compressive strength is from 2.6 to 2.9.

4.3 Results and discussions on flexural strength for hardened Concrete.

Flexural strength of concrete is one way of estimating the tensile strength of concrete. During this test the specimen is subjected to a bending moment. For a force applied downward on a member supported simply at its two ends, fibers above the neutral axis are generally subjected to compressive stresses and those below the neutral axis to tensile stresses.

Figure 4.3 Specimen to be tested for flexure

The flexural strength tests were conducted at seven and twenty eight days. These results are summarized in Table 4.2**.** The calculation of the flexural stress is as follows:

$C = D/2$ cm………………………………………………………………...……....…. [Eq. 4.1]

$M = PL/4$ N.m………………………………………………………...…...……..….. [Eq. 4.2]

$I = bd^3/12$ m4……………………………………………………….…......……... [Eq. 4.3]

$\sigma = MC/I$ MPa…………………………………………………………………......... [Eq. 4.4]

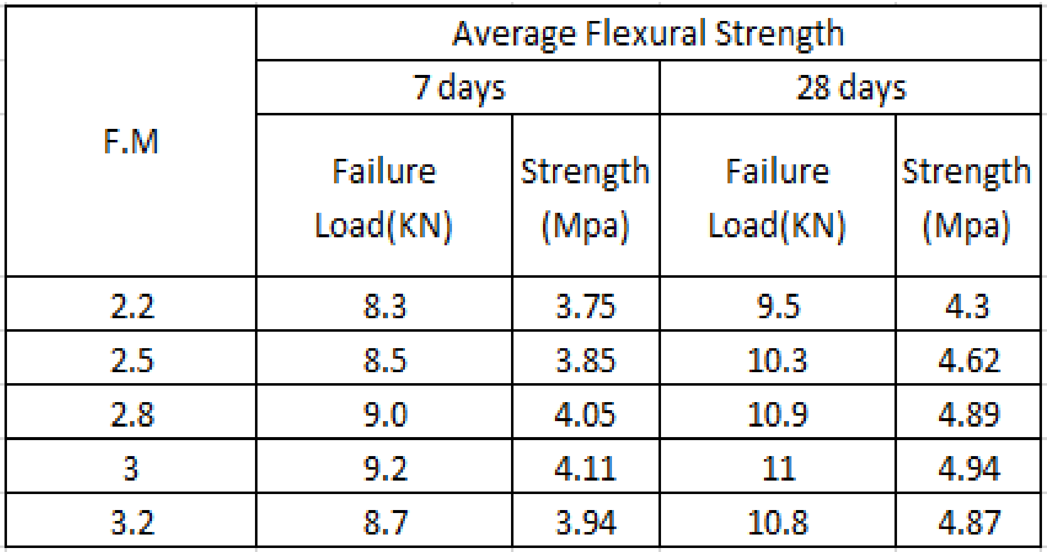
Where: P = Failure Load   σ = Bending strength

M = Maximum Moment   L = span of specimen

I = Moment of Inertia   D = depth of specimen

C = Centroidal depth   W = width of specimen

Table 4.2 Average flexural strength of the concretes



F.M	Average Flexural Strength			
	7 days		28 days	
	Failure Load(KN)	Strength (Mpa)	Failure Load(KN)	Strength (Mpa)
2.2	8.3	3.75	9.5	4.3
2.5	8.5	3.85	10.3	4.62
2.8	9.0	4.05	10.9	4.89
3	9.2	4.11	11	4.94
3.2	8.7	3.94	10.8	4.87

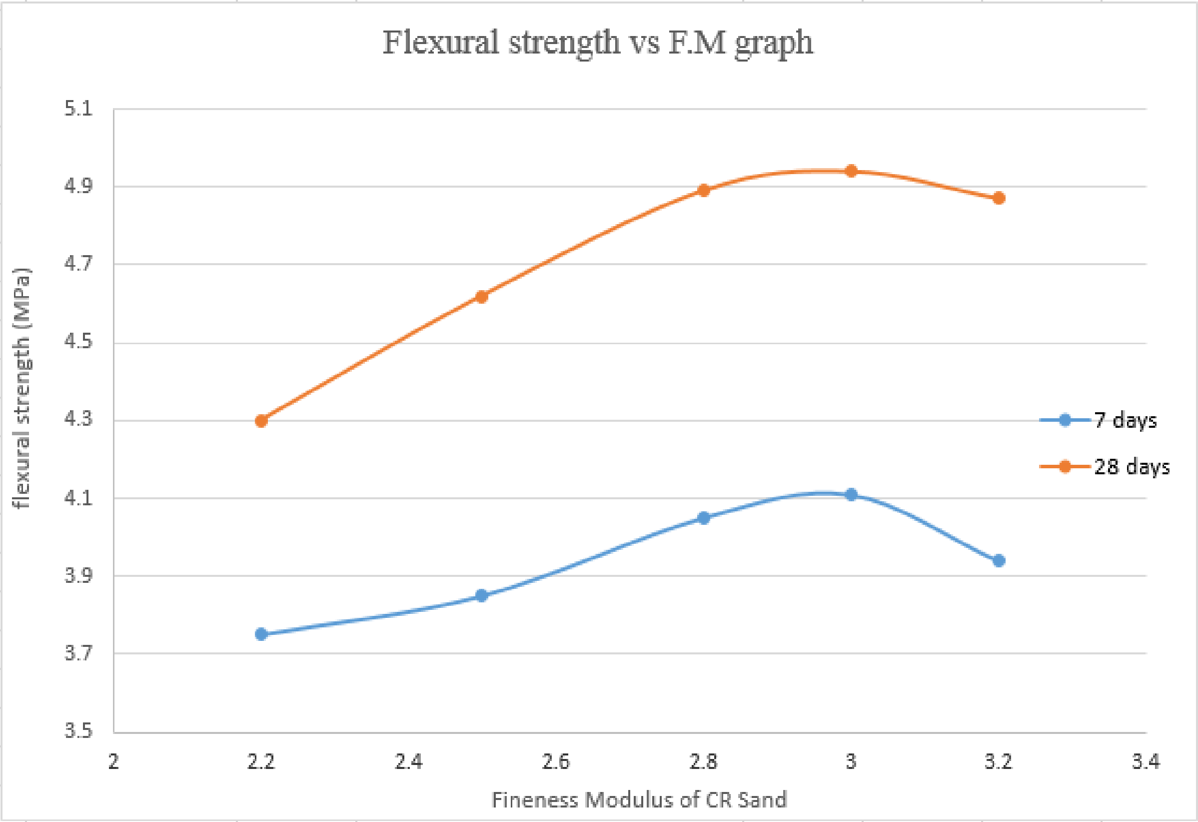


Figure 4.4 Flexural strength versus F.M of the CR Sand.

From the above figure the optimum Fineness Modulus range of the fine crushed sand to get the maximum Flexural strength is from 2.8 to 3.0.

4.4 Workability of Fresh Concrete Related to Optimum Fineness Modulus range of fine Crushed sand.

The results of the slump tests carried out on the fresh concrete gave an indication of the workability of the concrete.

Table (4.3) and Figure (4.5) shows the average Slump test results for concrete prepared using different fineness modulus of fine crushed stone and tested directly after mixing. The results revealed that there is an increment in the workability of fresh concrete with higher fineness modulus of fine crushed stone used in the concrete mixes. This leads to the fact that the workability of the fresh concrete mix increases with the coarser grading of the fine crushed sand. It is worth to mention that for the lowest Fineness Modulus of crushed stone, the standard hardened cubes were honeycombed and the mix was not workable which directly leaded to the lowest compressive strength recorded value.

Table 4.3: Workability of fresh concrete mixes measured by the average record of the Slump test (mm) for different Fineness Modulus of fine crushed stone used in the concrete mix.

Fineness Modulus	Slump Value (mm)	Recommended slump range (mm)
2.2	46	25-100
2.5	53	25-100
2.8	57	25-100
3.0	68	25-100
3.2	71	25-100

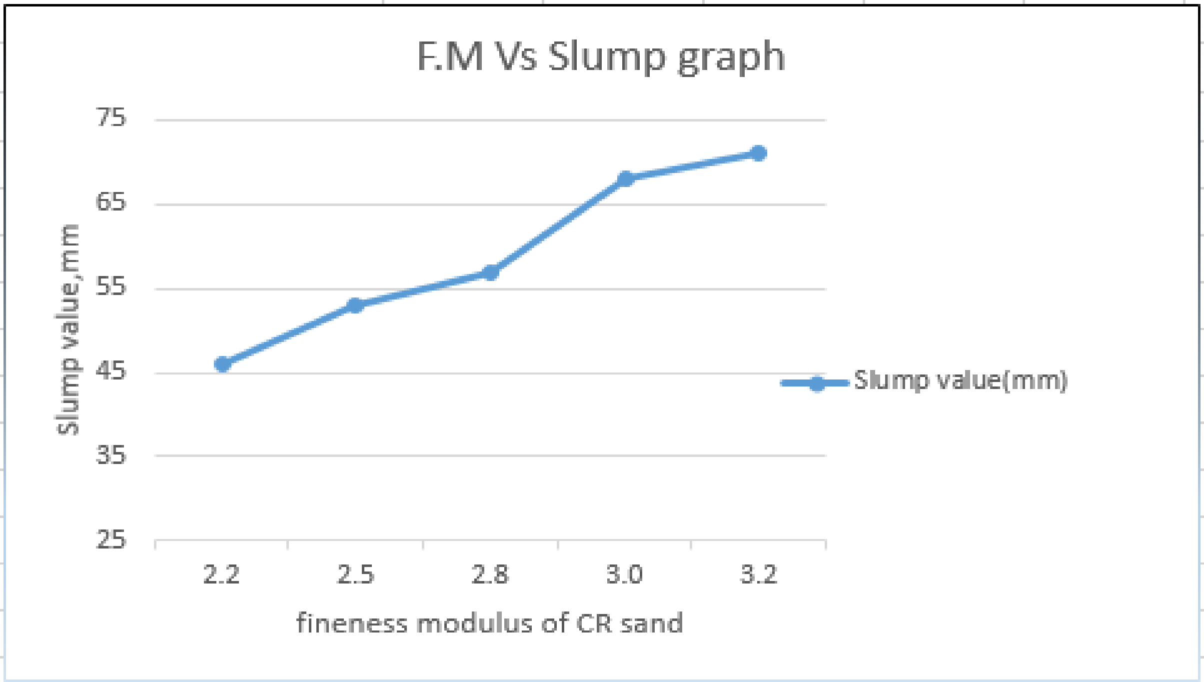


Figure 4.5 Workability of fresh concrete mixes measured by the average record of the Slump test (mm) for different fineness modulus of crushed stone sand used in the concrete mix.

Using optimum Fines modulus range for compressive and flexural strength which have found in the experiment, the slump value is between 50 and 68 these is a mix with considerable workability.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Suitability of CR sand fineness modulus in producing concrete for full replacement were studied and after the research work is done, the following conclusions are made and recommendations are forwarded:

1. As fineness modulus of crushed rock sand changes from 2.2 to 2.8 there is an increase in 28th day compressive strength of concrete and as fineness modulus of crushed rock sand changes from 2.8 to 3.2 the compressive strength decreased.
2. As fineness modulus of crushed rock sand changes from 2.2 to 3.0 there is an increase in 28th day flexural strength of concrete and as fineness modulus of sand changes from 3.0 to 3.2 the flexural strength decreased.
3. The research findings revealed that the optimum fineness modulus range of crushed Rock Sand to be used as fine aggregate in concrete mixes for compressive and flexural strength is from 2.6 to 3.0. The slump value of which the optimum fines modulus range makes as a workable mix.

5.2 Recommendation

1. Any grading of fine aggregate should be checked and compared with the ASTM grading requirements.
2. From the results of this research work the recommended optimum fineness modulus range is from 2.6 to 3.0.
3. The crusher, could be adjust the screen size so as to give a range of aggregate sizes.
4. Aggregate quarries, manufactures, and suppliers can use this research results in order to improve the different properties of their concrete mixes in terms of compressive strength, flexural strength and workability without extra cost by providing the fine crushed rock sand to the construction market.

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ANNEX A

MATERIAL PROPERTIES

A.1. Properties of Fine Aggregate

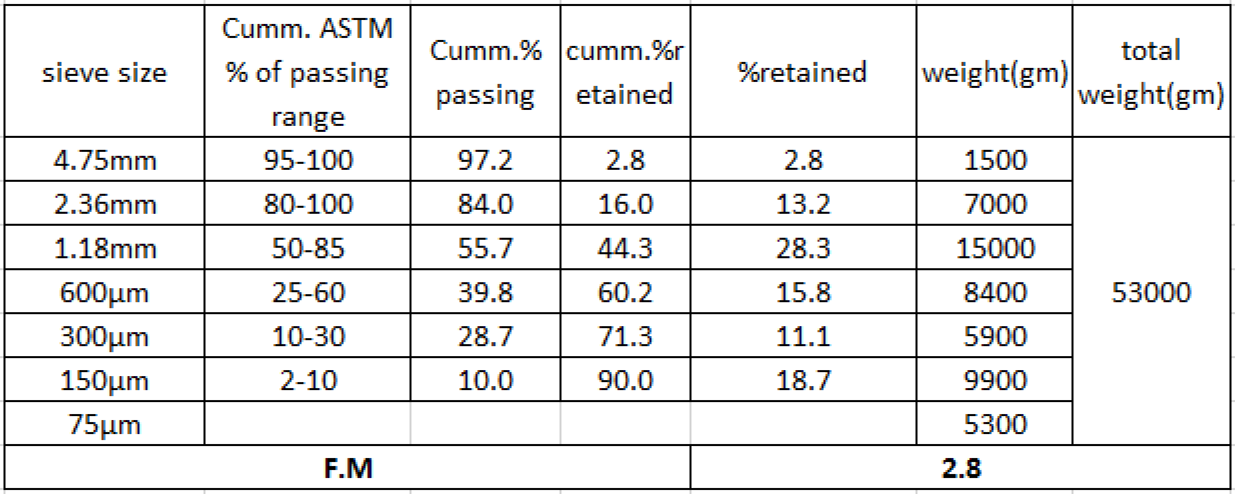
A.1.1. Silt content

Silt Content of CR Sand			
Sand type	Amount of silt deposited above the sand(cm)	Amount of clean sand(cm)	Silt content(%)
CR Sand	6	102	5.9

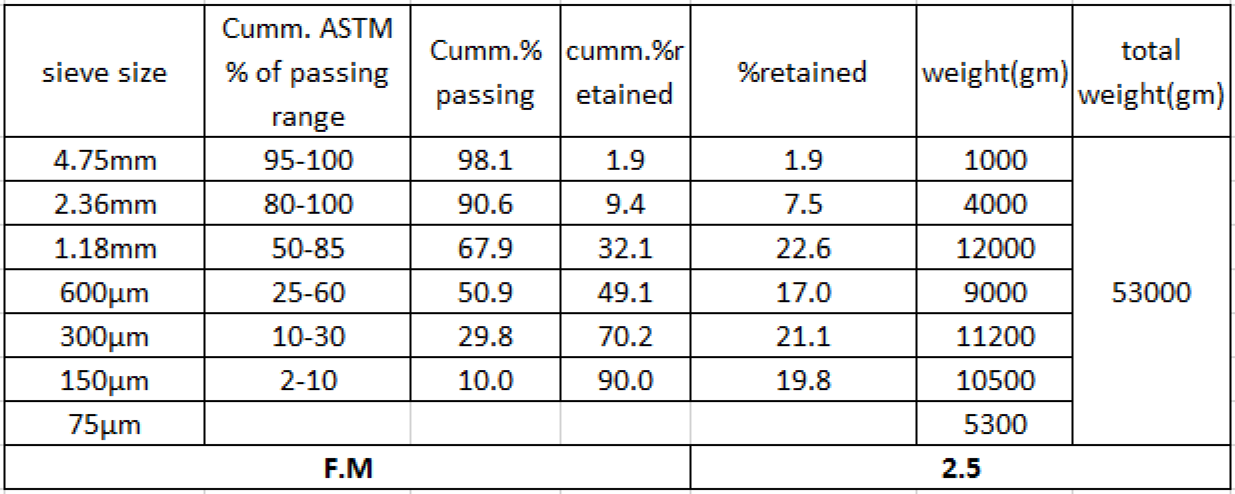
A.1.2. Sieve Analysis

sieve size	Cumm. ASTM % of passing range	Cumm.% passing	cumm.%retained	%retained	weight(gm)	total weight(gm)
4.75mm	95-100	95.3	4.7	4.7	2500	53000
2.36mm	80-100	80.2	19.8	15.1	8000	
1.18mm	50-85	50.0	50.0	30.2	16000	
600µm	25-60	29.2	70.8	20.8	11000	
300µm	10-30	13.2	86.8	16.0	8500	
150µm	2-10	9.6	90.4	3.6	1900	
75µm					5100	
F.M				**3.2**		

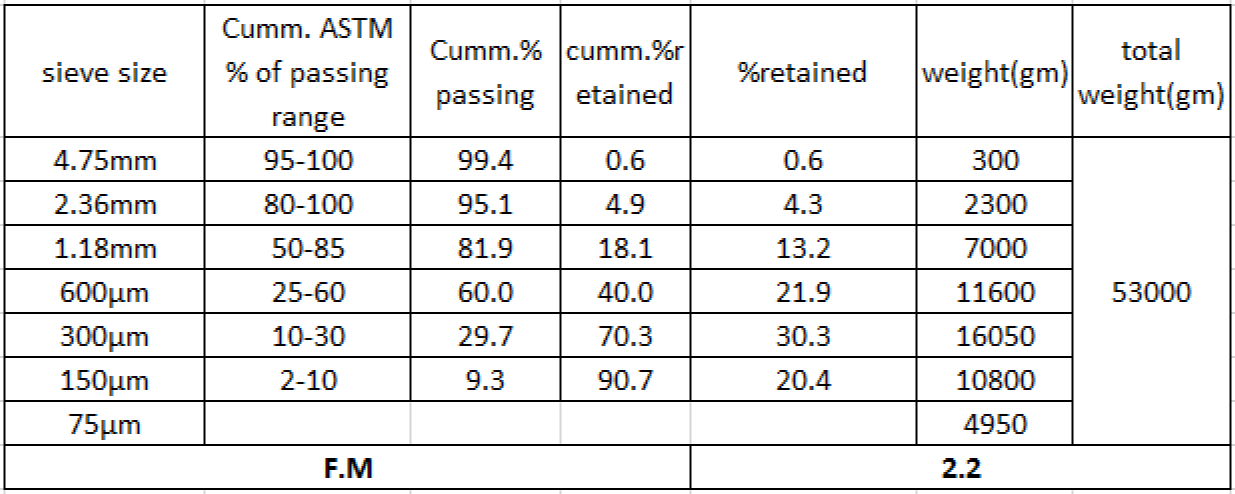
sieve size	Cumm. ASTM % of passing range	Cumm.% passing	cumm.%retained	%retained	weight(gm)	total weight(gm)
4.75mm	95-100	96.6	3.4	3.4	1800	53000
2.36mm	80-100	82.2	17.8	14.4	7650	
1.18mm	50-85	52.0	48.0	30.2	16000	
600µm	25-60	35.0	65.0	17.0	9000	
300µm	10-30	19.7	80.3	15.3	8100	
150µm	2-10	10.0	90.0	9.7	5150	
75µm					5300	
F.M				**3.0**		



sieve size	Cumm. ASTM % of passing range	Cumm.% passing	cumm.%retained	%retained	weight(gm)	total weight(gm)
4.75mm	95-100	97.2	2.8	2.8	1500	53000
2.36mm	80-100	84.0	16.0	13.2	7000	
1.18mm	50-85	55.7	44.3	28.3	15000	
600µm	25-60	39.8	60.2	15.8	8400	
300µm	10-30	28.7	71.3	11.1	5900	
150µm	2-10	10.0	90.0	18.7	9900	
75µm					5300	
F.M				**2.8**		

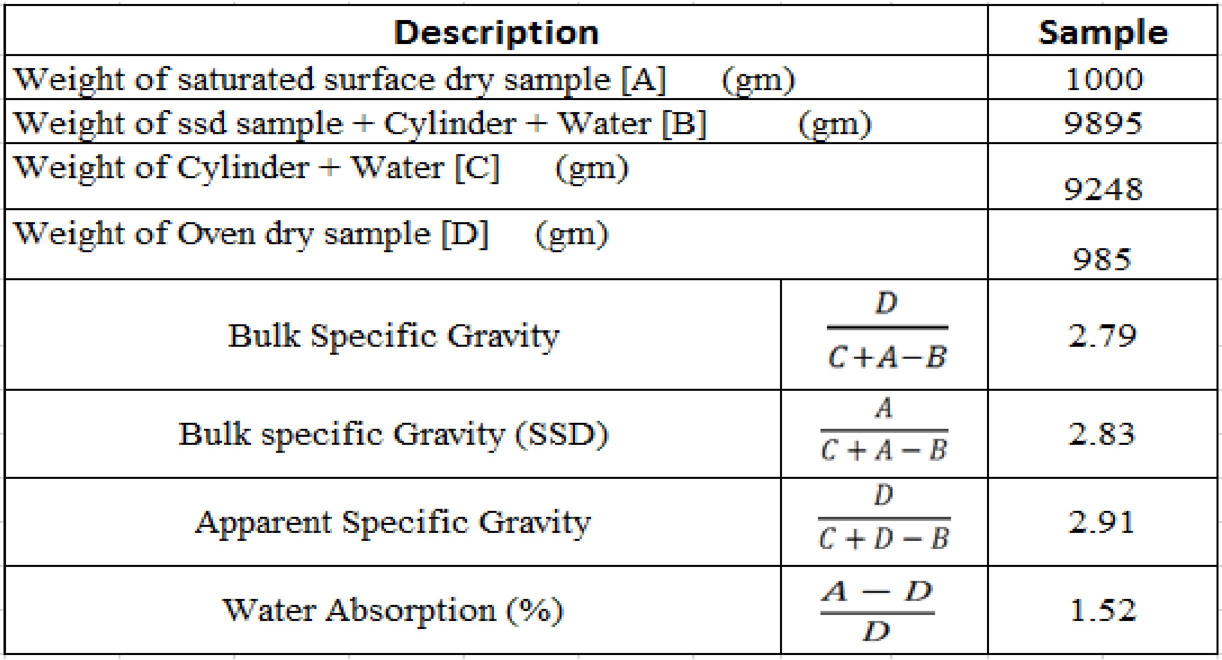


sieve size	Cumm. ASTM % of passing range	Cumm.% passing	cumm.%retained	%retained	weight(gm)	total weight(gm)
4.75mm	95-100	98.1	1.9	1.9	1000	53000
2.36mm	80-100	90.6	9.4	7.5	4000	
1.18mm	50-85	67.9	32.1	22.6	12000	
600µm	25-60	50.9	49.1	17.0	9000	
300µm	10-30	29.8	70.2	21.1	11200	
150µm	2-10	10.0	90.0	19.8	10500	
75µm					5300	
F.M				**2.5**		



sieve size	Cumm. ASTM % of passing range	Cumm.% passing	cumm.%retained	%retained	weight(gm)	total weight(gm)
4.75mm	95-100	99.4	0.6	0.6	300	53000
2.36mm	80-100	95.1	4.9	4.3	2300	
1.18mm	50-85	81.9	18.1	13.2	7000	
600µm	25-60	60.0	40.0	21.9	11600	
300µm	10-30	29.7	70.3	30.3	16050	
150µm	2-10	9.3	90.7	20.4	10800	
75µm					4950	
F.M				**2.2**		

A.1.3. Specific Gravity & Absorption Capacity



Description		**Sample**
Weight of saturated surface dry sample [A] (gm)		1000
Weight of ssd sample + Cylinder + Water [B] (gm)		9895
Weight of Cylinder + Water [C] (gm)		9248
Weight of Oven dry sample [D] (gm)		985
Bulk Specific Gravity	$\frac{D}{C+A-B}$	2.79
Bulk specific Gravity (SSD)	$\frac{A}{C+A-B}$	2.83
Apparent Specific Gravity	$\frac{D}{C+D-B}$	2.91
Water Absorption (%)	$\frac{A-D}{D}$	1.52

A.1.4. Moisture Content

Weight of Aggregate sample (A) = 500gm

Weight of oven dry sample (B) = 488gm

w= moisture content (%)

$$w = \frac{A-B}{B} * 100 = \frac{500-488}{488} * 100 = 2.46\%$$

A.1.5. Unit Weight

Cylindrical metal measure = 0.01m^3

Net weight of sample, 1 = 15.501

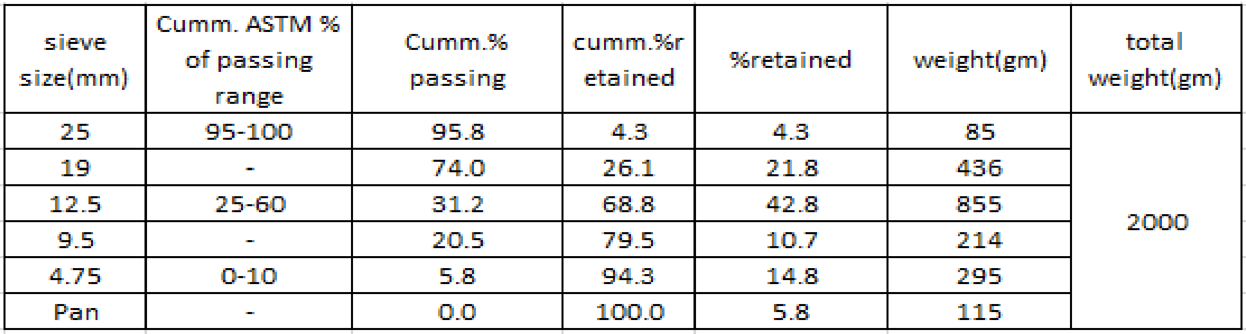
Net weight of sample, 2 = 15.611

Net weight of sample, 3 = 15.474

$$\text{Unit Weight} = \frac{15.501+15.611+15.474}{3*0.01} = 1552.9\text{kg/m}^3$$

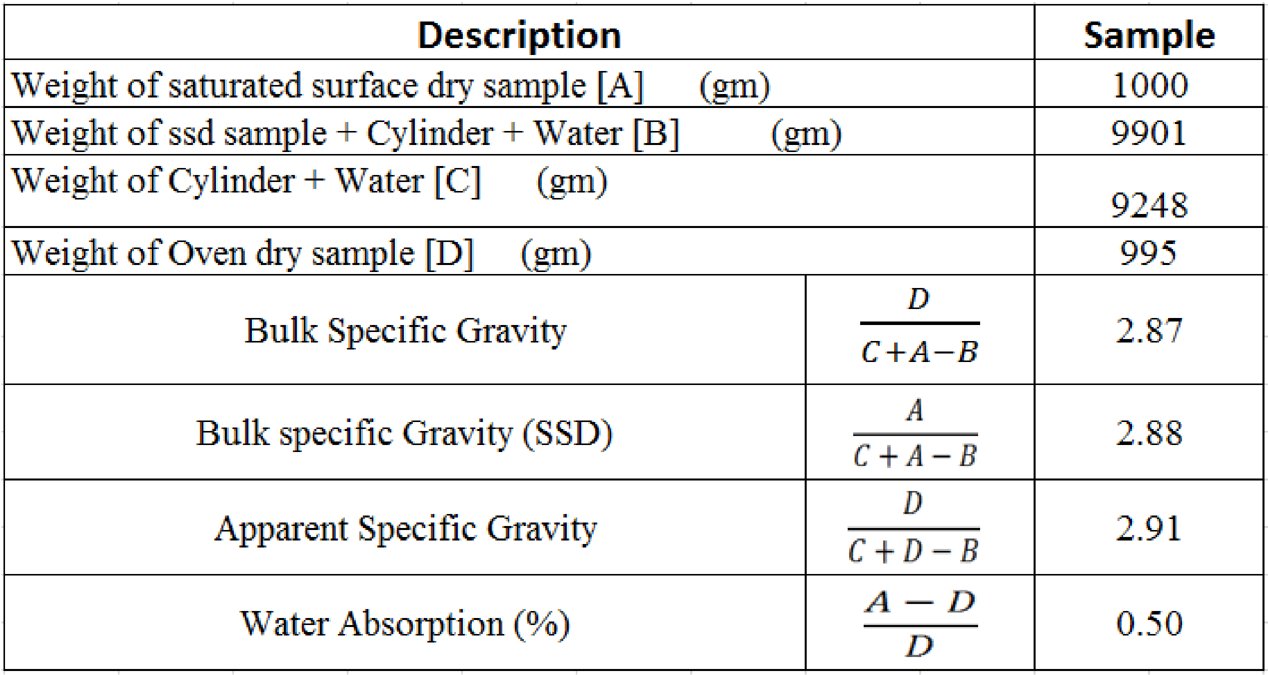
A.2. Properties of Coarse Aggregate

A.2.1. Sieve Analysis



sieve size(mm)	Cumm. ASTM % of passing range	Cumm.% passing	cumm.%retained	%retained	weight(gm)	total weight(gm)
25	95-100	95.8	4.3	4.3	85	2000
19	-	74.0	26.1	21.8	436	
12.5	25-60	31.2	68.8	42.8	855	
9.5	-	20.5	79.5	10.7	214	
4.75	0-10	5.8	94.3	14.8	295	
Pan	-	0.0	100.0	5.8	115	

A.2.2. Specific Gravity, Absorption Capacity



Description		Sample
Weight of saturated surface dry sample [A] (gm)		1000
Weight of ssd sample + Cylinder + Water [B] (gm)		9901
Weight of Cylinder + Water [C] (gm)		9248
Weight of Oven dry sample [D] (gm)		995
Bulk Specific Gravity	$\frac{D}{C+A-B}$	2.87
Bulk specific Gravity (SSD)	$\frac{A}{C+A-B}$	2.88
Apparent Specific Gravity	$\frac{D}{C+D-B}$	2.91
Water Absorption (%)	$\frac{A-D}{D}$	0.50

A.2.3. Water Content

Weight of Aggregate sample (A) = 500gm

Weight of oven dry sample (B) = 492gm

w= moisture content (%)

$$w = \frac{A-B}{B} * 100 = \frac{500-492}{492} * 100 = 1.63\%$$

A.2.4. Unit Weight

Cylindrical metal measure = 0.01m^3

Net weight of sample, 1 = 16.272

Net weight of sample, 2 = 16.052

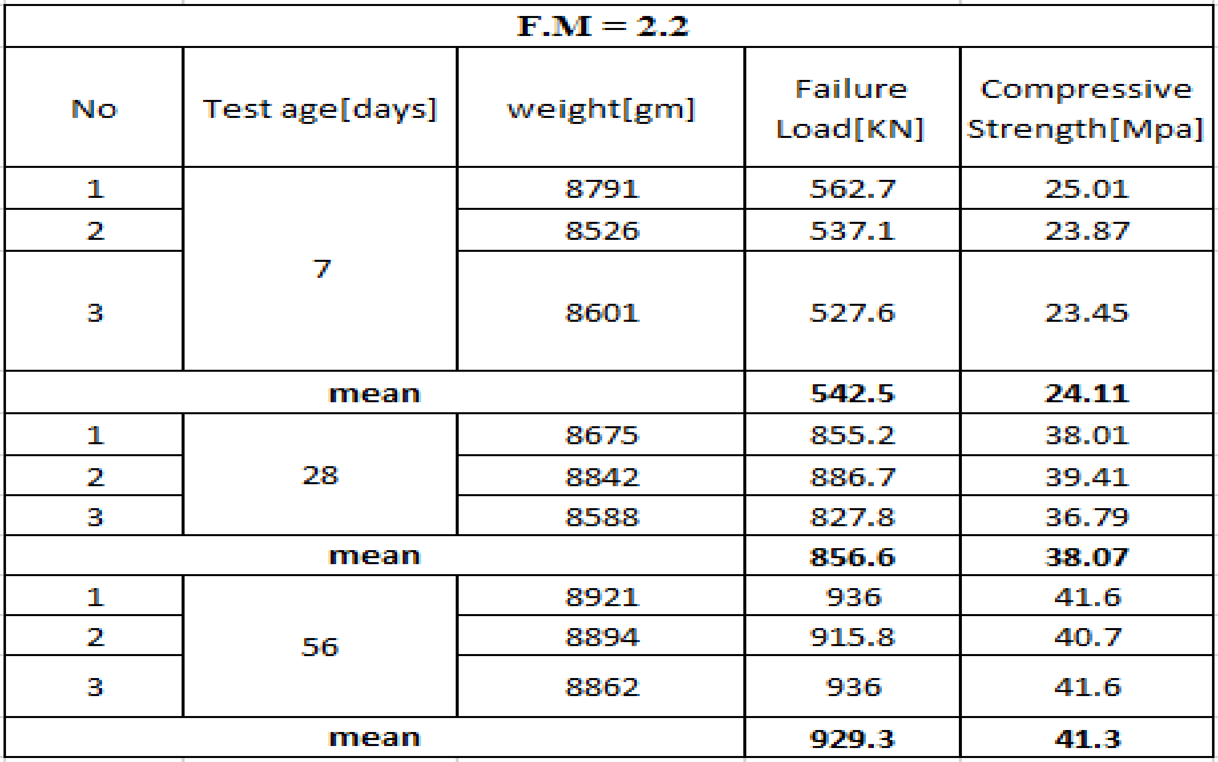
Net weight of sample, 3 = 16.189

$$\text{Unit Weight} = \frac{16.272+16.052+16.189}{3*0.01} = 1617.11 kg/m^3$$

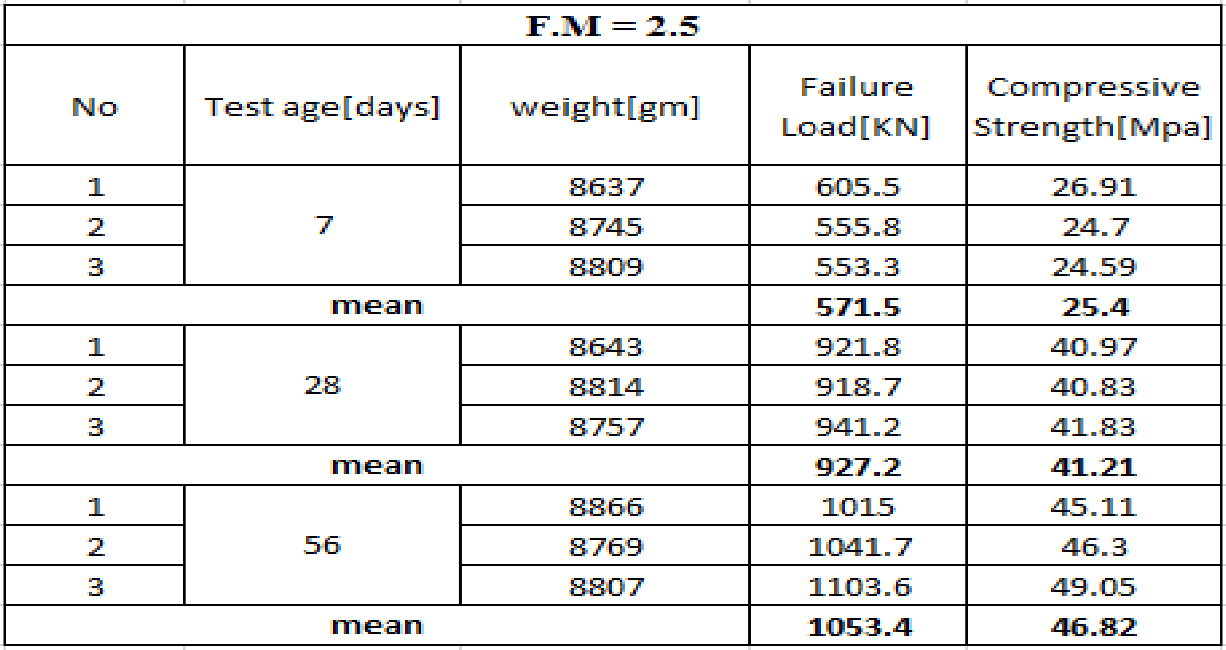
ANNEX B

Test Results

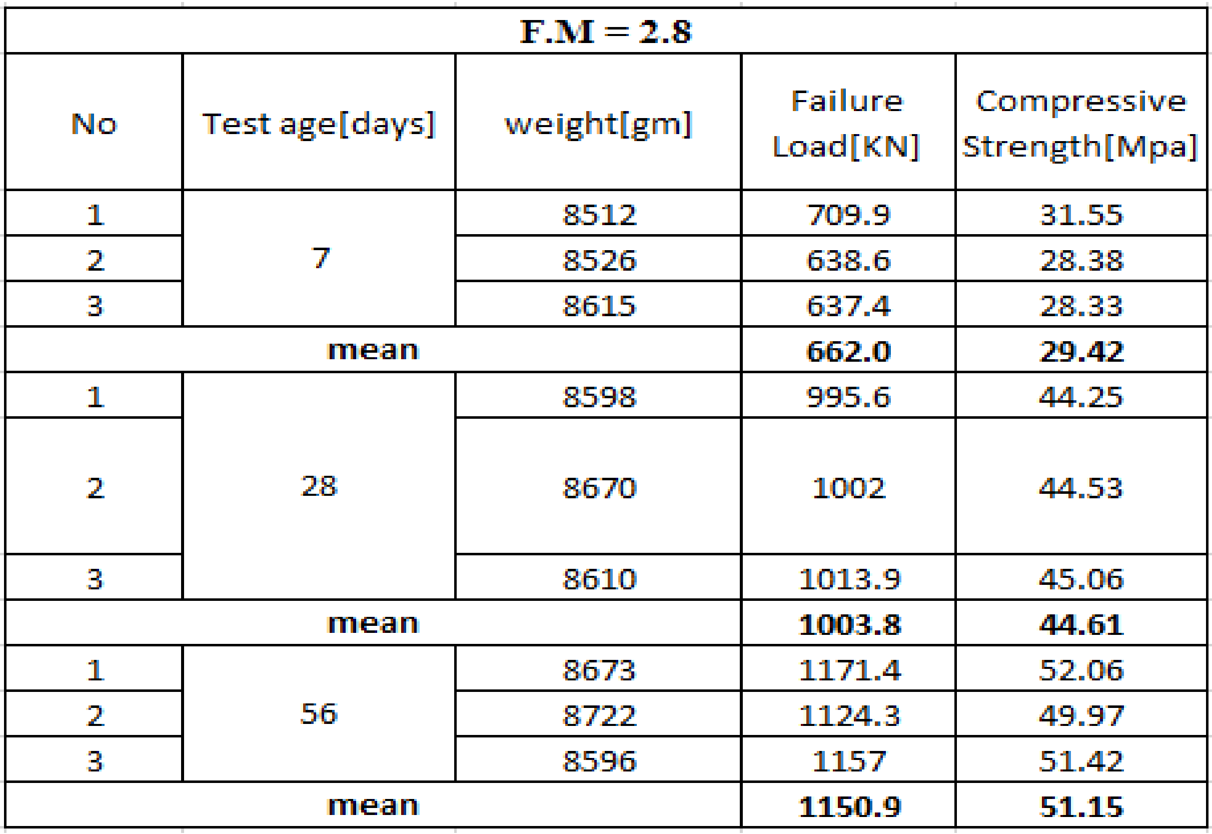
B.1 Cube Compressive Strength Test Result of C-25 Concrete



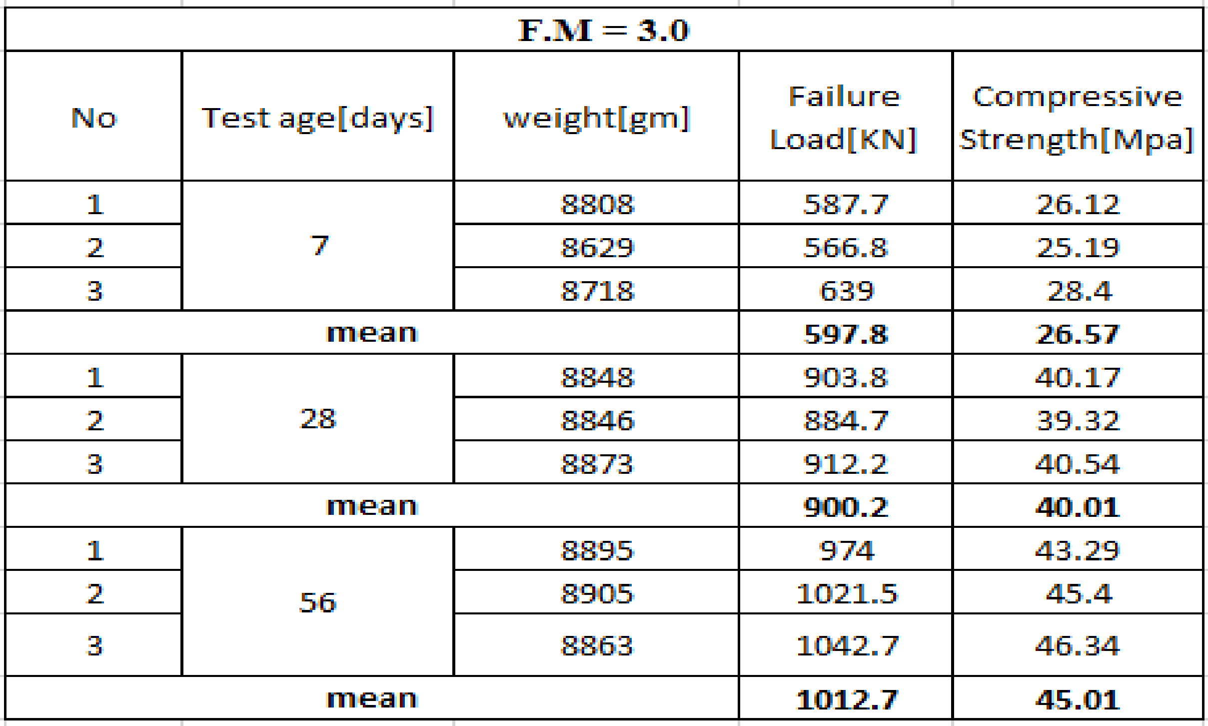
F.M = 2.2				
No	Test age[days]	weight[gm]	Failure Load[KN]	Compressive Strength[Mpa]
1	7	8791	562.7	25.01
2		8526	537.1	23.87
3		8601	527.6	23.45
mean			**542.5**	**24.11**
1	28	8675	855.2	38.01
2		8842	886.7	39.41
3		8588	827.8	36.79
mean			**856.6**	**38.07**
1	56	8921	936	41.6
2		8894	915.8	40.7
3		8862	936	41.6
mean			**929.3**	**41.3**



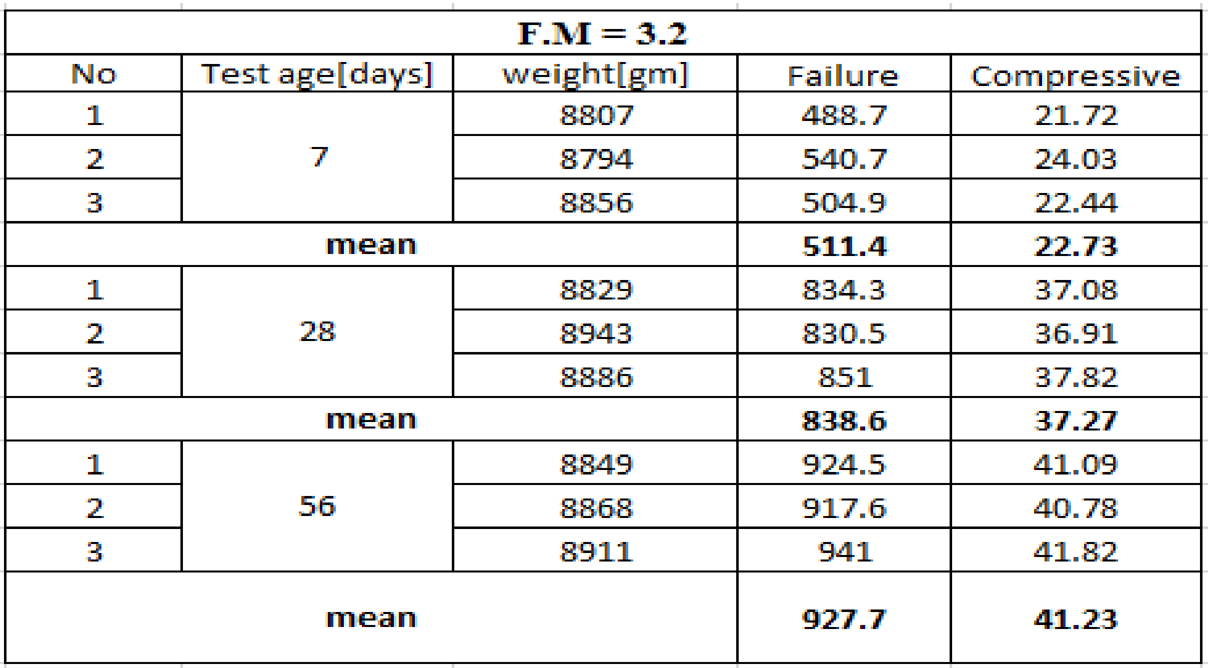
F.M = 2.5				
No	Test age[days]	weight[gm]	Failure Load[KN]	Compressive Strength[Mpa]
1	7	8637	605.5	26.91
2		8745	555.8	24.7
3		8809	553.3	24.59
mean			**571.5**	**25.4**
1	28	8643	921.8	40.97
2		8814	918.7	40.83
3		8757	941.2	41.83
mean			**927.2**	**41.21**
1	56	8866	1015	45.11
2		8769	1041.7	46.3
3		8807	1103.6	49.05
mean			**1053.4**	**46.82**



F.M = 2.8				
No	Test age[days]	weight[gm]	Failure Load[KN]	Compressive Strength[Mpa]
1	7	8512	709.9	31.55
2		8526	638.6	28.38
3		8615	637.4	28.33
mean			**662.0**	**29.42**
1	28	8598	995.6	44.25
2		8670	1002	44.53
3		8610	1013.9	45.06
mean			**1003.8**	**44.61**
1	56	8673	1171.4	52.06
2		8722	1124.3	49.97
3		8596	1157	51.42
mean			**1150.9**	**51.15**

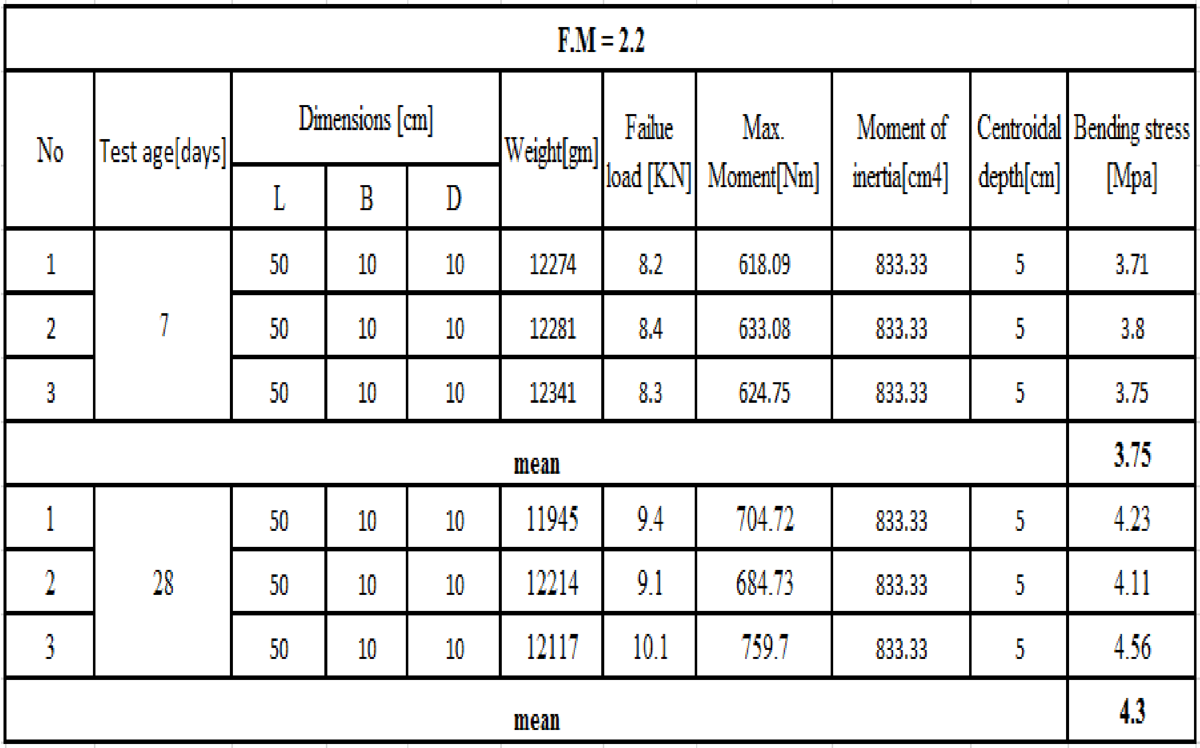


F.M = 3.0				
No	Test age[days]	weight[gm]	Failure Load[KN]	Compressive Strength[Mpa]
1	7	8808	587.7	26.12
2		8629	566.8	25.19
3		8718	639	28.4
mean			**597.8**	**26.57**
1	28	8848	903.8	40.17
2		8846	884.7	39.32
3		8873	912.2	40.54
mean			**900.2**	**40.01**
1	56	8895	974	43.29
2		8905	1021.5	45.4
3		8863	1042.7	46.34
mean			**1012.7**	**45.01**

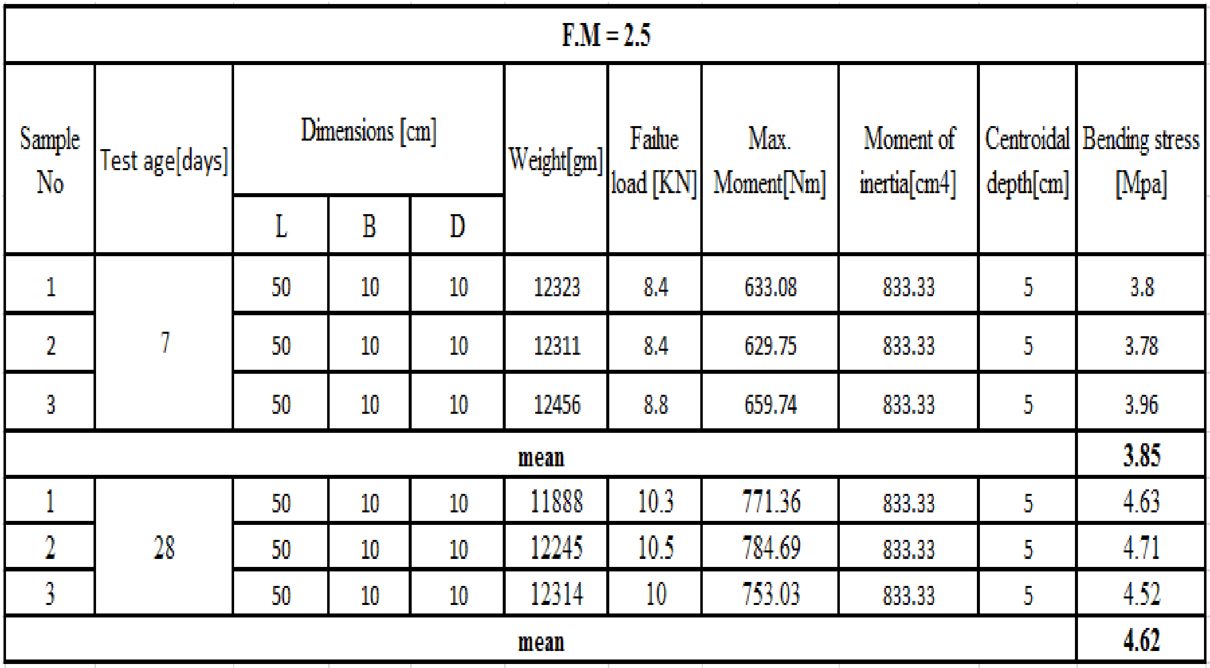


F.M = 3.2				
No	Test age[days]	weight[gm]	Failure	Compressive
1	7	8807	488.7	21.72
2		8794	540.7	24.03
3		8856	504.9	22.44
mean			**511.4**	**22.73**
1	28	8829	834.3	37.08
2		8943	830.5	36.91
3		8886	851	37.82
mean			**838.6**	**37.27**
1	56	8849	924.5	41.09
2		8868	917.6	40.78
3		8911	941	41.82
mean			**927.7**	**41.23**

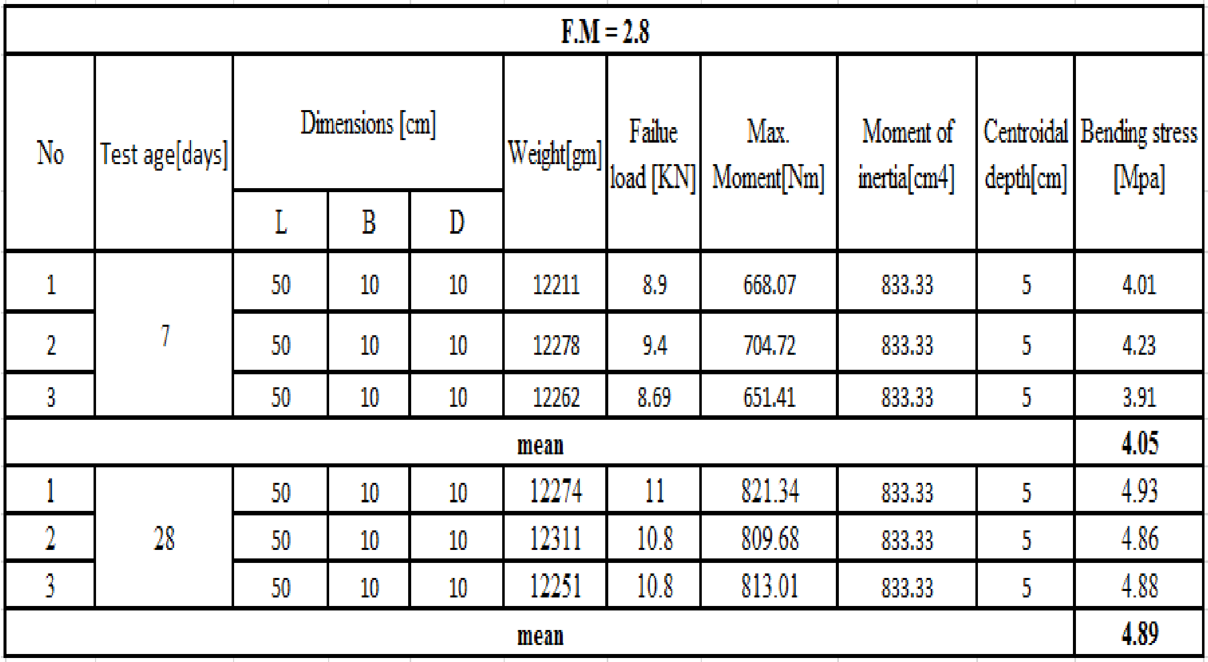
B.2 Flexural Strength Test Result of C-25 Concrete



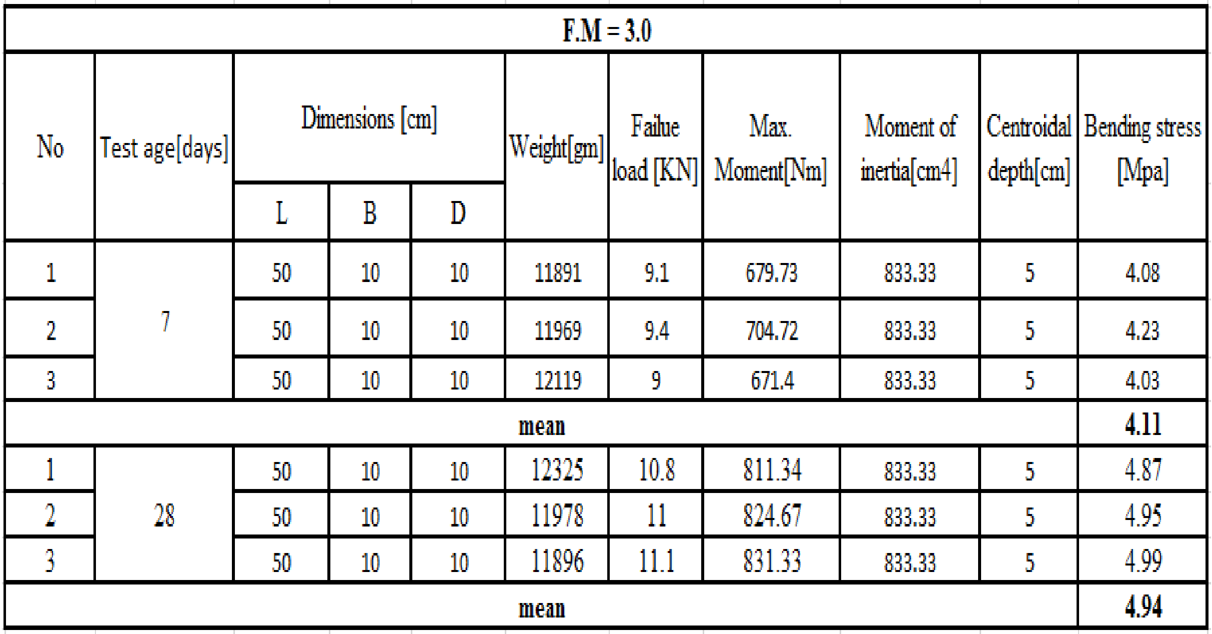
F.M = 2.2										
No	Test age[days]	Dimensions [cm]			Weight[gm]	Failue load [KN]	Max. Moment[Nm]	Moment of inertia[cm4]	Centroidal depth[cm]	Bending stress [Mpa]
		L	B	D						
1	7	50	10	10	12274	8.2	618.09	833.33	5	3.71
2		50	10	10	12281	8.4	633.08	833.33	5	3.8
3		50	10	10	12341	8.3	624.75	833.33	5	3.75
mean										**3.75**
1	28	50	10	10	11945	9.4	704.72	833.33	5	4.23
2		50	10	10	12214	9.1	684.73	833.33	5	4.11
3		50	10	10	12117	10.1	759.7	833.33	5	4.56
mean										**4.3**



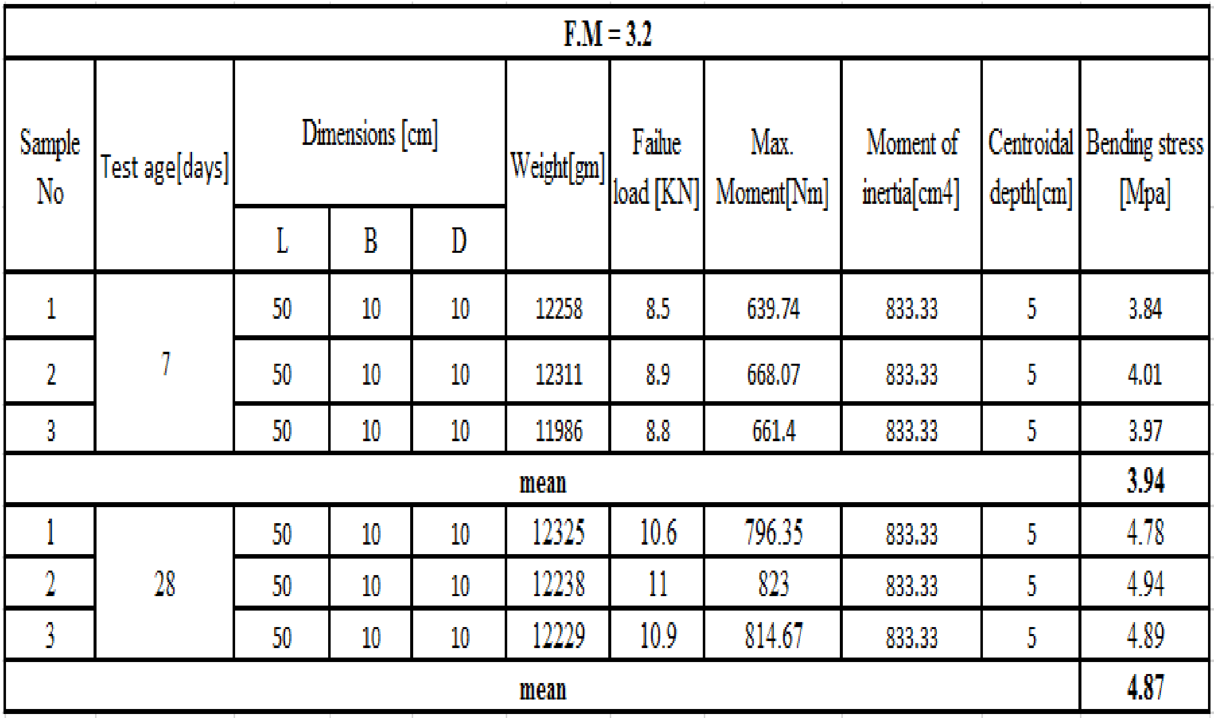
F.M = 2.5										
Sample No	Test age[days]	Dimensions [cm]			Weight[gm]	Failue load [KN]	Max. Moment[Nm]	Moment of inertia[cm4]	Centroidal depth[cm]	Bending stress [Mpa]
		L	B	D						
1	7	50	10	10	12323	8.4	633.08	833.33	5	3.8
2		50	10	10	12311	8.4	629.75	833.33	5	3.78
3		50	10	10	12456	8.8	659.74	833.33	5	3.96
mean										**3.85**
1	28	50	10	10	11888	10.3	771.36	833.33	5	4.63
2		50	10	10	12245	10.5	784.69	833.33	5	4.71
3		50	10	10	12314	10	753.03	833.33	5	4.52
mean										**4.62**



F.M = 2.8										
No	Test age[days]	Dimensions [cm]			Weight[gm]	Failue load [KN]	Max. Moment[Nm]	Moment of inertia[cm4]	Centroidal depth[cm]	Bending stress [Mpa]
		L	B	D						
1	7	50	10	10	12211	8.9	668.07	833.33	5	4.01
2		50	10	10	12278	9.4	704.72	833.33	5	4.23
3		50	10	10	12262	8.69	651.41	833.33	5	3.91
mean										**4.05**
1	28	50	10	10	12274	11	821.34	833.33	5	4.93
2		50	10	10	12311	10.8	809.68	833.33	5	4.86
3		50	10	10	12251	10.8	813.01	833.33	5	4.88
mean										**4.89**



F.M = 3.0										
No	Test age[days]	Dimensions [cm]			Weight[gm]	Failue load [KN]	Max. Moment[Nm]	Moment of inertia[cm4]	Centroidal depth[cm]	Bending stress [Mpa]
		L	B	D						
1	7	50	10	10	11891	9.1	679.73	833.33	5	4.08
2		50	10	10	11969	9.4	704.72	833.33	5	4.23
3		50	10	10	12119	9	671.4	833.33	5	4.03
mean										**4.11**
1	28	50	10	10	12325	10.8	811.34	833.33	5	4.87
2		50	10	10	11978	11	824.67	833.33	5	4.95
3		50	10	10	11896	11.1	831.33	833.33	5	4.99
mean										**4.94**



F.M = 3.2										
Sample No	Test age[days]	Dimensions [cm]			Weight[gm]	Failue load [KN]	Max. Moment[Nm]	Moment of inertia[cm4]	Centroidal depth[cm]	Bending stress [Mpa]
		L	B	D						
1	7	50	10	10	12258	8.5	639.74	833.33	5	3.84
2		50	10	10	12311	8.9	668.07	833.33	5	4.01
3		50	10	10	11986	8.8	661.4	833.33	5	3.97
mean										**3.94**
1	28	50	10	10	12325	10.6	796.35	833.33	5	4.78
2		50	10	10	12238	11	823	833.33	5	4.94
3		50	10	10	12229	10.9	814.67	833.33	5	4.89
mean										**4.87**

ANNEX C

Sample Photo Gallery Taken During the Research

Photo 1. Coarse aggregate under specific Gravity test

Photo 2. Aggregates under oven

Photo 3. Aggregates under soaked (submerged)

Photo 4. Cube specimens prepared

Phot 5. Specimens under curing.

Photo 6. Silt test

Photo 7. Sieve analysis test

Photo 8. CR Sand sample