JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIROMENTAL ENGINEERING

STRUCTURAL ENGINEERING STREAM

Assessment of concrete strength by comparing river and manufactured sand used in Jimma area.

A Thesis submitted to the School of Graduate Studies of Jimma University in Partial fulfillment of the Requirements for the Degree of Master of Science in Structural Engineering.

By

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Acronyms

ACI	American Concrete Institute
ASTM	American Society for Testing of Materials
BS	British Standard
EBCS	Ethiopian Building Code of Standards
FM	Fineness Modulus
MFA	Manufactured Fine aggregate
MPa/s	Mega Pascal per second
MS	Manufactured Sand
NS	Natural Sand
PPC	Portland Pozzolana Cement
UK	United Kingdom
US	United States
W/C	Water Cement Ratio

ABSTRACT

In ordinary structural concretes the aggregate constitutes 60 to 75 percent of the volume of hardened mass. Aggregates, which majority of them occurs naturally, are subjected to a wide range of variability and quality problems. Thus by assessing the quality of the aggregate we can say a lot about the quality of the concrete produced by it.

Fine aggregate constitutes 30 to 40 percent of the overall aggregate volume available in the hardened concrete. With this in mind this study focuses on the assessment of fine aggregate material available in Jimma area to satisfy the requirements for compressive and tensile strength of concrete. Mostly used fine aggregate materials in Jimma town are natural and manufactured sand. Thus experiment has been undertaken to investigate the suitability of both types of fine aggregate materials to produce C-25 and C-30 concrete.

Initially samples were taken from natural and manufactured sand and checked if they can satisfy physical requirements set by different standards. Then five combinations of natural sand and manufactured sand at an interval of 25% replacement (i.e. 100 NS +0 MS, 75 NS + 25 MS, 50NS + 50MS, 25NS + 75MS and 0NS+100 MS) were prepared for C-25 and C-30 grade concrete. The properties of these mixes were assessed both at the fresh and hardened state.

The test results showed that for both, C-25 and C-30 concrete grades, the concrete mix with 50%MS+ 50% NS achieved a higher compressive strength than using with other proportions of manufactured and natural sand. But the manufactured sand has a gradation problem which is due to the lack of controlled production procedure and quality inspection.

The mix proportion with 100% natural sand showed compressive and tensile strength below the requirements for C-25 concrete grade.

Key Words: concrete**,** natural sand, manufactured sand, Jimma, compressive strength**,** tensile strength

Chapter 1 INTRODUCTION

1.1 GENERAL

Concrete is one of the oldest construction materials in the construction industry and it is widely used throughout the world. It is generally known that, 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 to obtain the optimum product in quality and economy for any use (1).

Good concrete, whether plain, reinforced or pre-stressed, should be strong enough to carry super imposed loads during its service life. Other essential properties include impermeability, durability, minimum amount of shrinkage, and cracking (1).

The quality of good concrete is dependent mainly on the quality of its constituent materials. It is a known fact that concrete making aggregates constitute the lion share of the total volume of concrete. In addition, unlike water and cement, which do not alter in any particular characteristic except in the quantity, in which they are used, the aggregate component is infinitely variable in terms of shape and grading. These shows the importance of the care that should be taken in processing and supplying aggregates for concrete production (1).

The constituents of concrete which most of them are naturally occurring materials are subjected to a wide range of variability. The first constituent, water, is a relatively non variable and usually available in a condition to be used for concrete readily. The second constituent, cement, is also a factory product that it is relatively easy to control its production process and its quality. However, the third constituents of concrete, which are coarse and fine aggregates, are usually naturally occurring that they are subjected to a wide range of variability.

Fine aggregate is smaller filler which can be found naturally (river sand) or passes through manufacturing process (manufactured sand). It ranges in size from 4.75mm to 150µm according to U.S standard sieve sizes. A good fine aggregate should always be free of organic impurities, clay, or any deleterious material or excessive filler of size smaller than 150µm. It should preferably have a well-graded combination conforming to the ASTM sieve analysis standards (2).

Fine aggregate constitutes 30 to 40 percent of the overall aggregate volume available in the hardened concrete. Thus keeping other variables which alter the quality of concrete like cement, water and coarse aggregate within the required standards we can surely say that the quality of fine aggregate available in concrete has a greater impact on the quality of the concrete produced.

1.2 STATEMENT OF THE PROBLEM

Fine aggregates may be produced from igneous, sedimentary, or metamorphic rocks, but the presence or absence of any geological type does not, by itself, make an aggregate suitable or unsuitable for use in concrete. The acceptance of an aggregate for use in concrete on a particular job should be based upon specific information obtained from tests used to measure the aggregate quality, or upon its service record, or both (3).

Sheferaw dinku studied the use of manufactured sand in concrete production and comparison of costs for each concrete mixes based on the price of the concrete material collected from Addis Ababa, Nazareth, Awassa, Mekelle and Jimma towns. He concluded that in general by using manufactured sand in partial or full replacement to natural sand, it is possible to achieve a better strength than the natural sand mix alone without significant cost variation (4).

Crushed rock sand has been correctly identified as an alternative to river sand. But many studies suggest that unprocessed rock fines or quarry dust should not be regarded as crushed rock sand due to the high failure rate in respect of grading requirements. Crushed rock sand or fine aggregate from crushed rock should be produced, in the same manner as other quarry products using appropriate machinery and production techniques (5)

Here in the study area a by-product in crushing factories are used as fine aggregate materials for pavement and concrete production. The manufactured sand is not produced purposefully for use in concrete instead it is a by-product of the coarse aggregate crushing process. In view of scarcities of good quality natural sand on the locality and due to the fact that the mining of this natural sand is a direct and obvious cause of environmental degradation the crushed rock sand can be a viable alternative to the natural sand by fully or partially replacing it, if the basic requirements to be a good fine aggregate for concrete production are fulfilled.

1.2 OBJECTIVES

General Objective

The main objective of this research is to assess suitability of manufactured fine aggregate materials and compare with natural sand used in Jimma area for the production of good quality concrete by comparing the strength of the concrete.

Specific objectives

- To determine whether the manufactured sand used in Jimma area fulfill the requirements of the basic standards to be a good fine aggregate material.
- To analyze if the manufactured sand used in Jimma area improves the concrete strength.
- To determine the optimum blending percentage of natural sand and manufactured sand to produce a good quality concrete

1.3 SCOPE AND LIMITATIONS

The study's scope and limitations are given as follows:-

- One selected representative natural (river) sand and manufactured sand samples used in Jimma area due to the time and the budget specified for this study.
- One selected representative coarse aggregate sample found in Jimma town so as to keep ingredients of concrete other than fine aggregate consistent with the concrete produced in Jimma town.
- Portland Pozzolana cement (PPC) because of the wide availability and usability of this type of cement in the locality.
- C-25 and C-30 concrete grades for the compressive strength test because most construction concrete in the study area uses this concrete grades.
- C-25 for the tensile strength test because the result can be projected to the C-30 concrete.
- No cost comparison is done; cost comparison on the same study area with the same materials is already available.

Chapter 2 LITRETURE REVIEW

2.1 Concrete

Concrete is a composite material composed of coarse granular material (the aggregate or filler) embedded in a hard matrix of material (the cement or binder) that fills the space between the aggregate particles and glues them together. We can also consider concrete as a composite material that consists essentially of a binding medium within which are embedded particles or fragments of aggregates.

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. The selection of materials and choice of method of construction is not easy, since many variables affect the quality of the concrete produced, and both quality and economy must be considered. (4)

2.2 Concrete constituent materials

Concrete is a mixture of cement, aggregate, water and air. Variation in the properties or proportions of this constituent, as well as variations in transport, placing and compaction of concrete leads to variation in the strength of the final concrete.

2.2.1 Cement.

A concrete made with pozzolanic, hydraulic cement, developed by the Romans in 75 B.C. was used in building the theater at Pompeii and the Roman baths. The cement was a ground mix of lime and volcanic ash containing silica and aluminum, found near Pozzuoli, Italy, hence the name, pozzolanic cement (6).

According to the type of cement used, there are many different kinds of concrete. For instance, Portland cement concrete, asphalt concrete, and epoxy concrete. In concrete construction, the Portland cement concrete is utilized the most (1).

2.2.1.1 Portland Cement

Portland cement is by far the most important member of the family of hydraulic cements—that is, cements that harden through chemical interaction with water. The first patent for "Portland" cement was taken out in England in 1824 by Joseph Aspdin, though it was probably not a true Portland cement; the first true Portland cements were produced about 20 years later. Since then, many improvements have been made to cement production, leading to the sophisticated, though common, cements that are now so widely available (7).

Table 2.1 : Approximate Chemical Compositions of the Principal Types of Portland cement

ASTM Designation	Common Name	Percent by weight					Fineness
		C_3S	C_2S	C_3A	C_4AF	CSH_2	
Type I	Ordinary	50	25	12	8	5	350
Type II	Modified	45	30	7	12	5	350
Type III	High early strength	60	15	10	8	5	450
Type IV	Low heat	25	50	5	12	4	300
Type V	Sulfate resistant	40	40	4	10	4	350

a. Ordinary Portland cement

Ordinary Portland (Type-I) cement is suitable for general concrete construction when there is no exposure to sulphates in the soil. The standard requires that it is made from 95 to 100 percent of Portland cement clinker and 0 to 5 percent of minor additional constituents. Minor additional constituents are one or more of the other cementitious materials or filler. Filler is defined as any natural or inorganic mineral material other than a cementitious material (1).

Variations in its composition may produce a difference of up to ±20 % in the compressive strength of concrete that is made with it, but uniform results are obtainable by drawing cement from one source of supply (1).

Table 2.2 : Typical Compound Composition of Ordinary Portland cement (7)

Chemical formula	Shorthand notation	Chemical name	Weight Percent
$3CaO.SiO_2$	C_3S	Tricalcium silicate	50
$2CaO.SiO_2$	C_2S	Dicalcium silicate	25
$3CaO.AL_2O_3$	C_3A	Tricalcium aluminates	12
$4CaO.AL_2O_3.Fe_2O_3$	C_4AF	Tetracalcium aluminoferrite	8
$CaSO_4.2H_2O$	CSH_2	Calcium sulfate dehydrate (gypsum)	3.5

b. Portland Pozzolana cement

Portland pozzolana cements are blends of Portland cement and a pozzolanic material. The role of the pozzolan is to react slowly with the calcium hydroxide that is liberated during cement hydration. This tends to reduce the heat of hydration and the early strength but can increase the ultimate strength of the material. These cements tend to be more resistant to sulfate attack and to the alkali–aggregate reaction (7).

2.2.1.2 Hydration of Portland cement

The hydration reactions that take place between finely ground Portland cement and water is highly complex, because the individual cement grains vary in size and composition. As a consequence, the resulting hydration products are also not uniform; their chemical composition and micro structural characteristics vary not only with time but also with their location within the concrete. The basic characteristics of the hydration of Portland cement may be described as follows: (7)

- As long as the individual cement grains remain separated from each other by water, the cement paste remains fluid.
- The products of the hydration reactions occupy a greater volume than that occupied by the original cement grains.
- As the hydration products begin to intergrow, setting occurs.
- As the hydration reactions continue, additional bonds are formed between the cement grains, leading to strengthening of the system.

2.2.1.3 Performance of Different Cements in Concrete

The compositions of each of the five ASTM types of cements may vary widely from cement to cement, due to variations in locally available raw materials, kiln design, burning conditions, and so on. Their fineness may also be quite variable. As a result, their cementitious properties may also vary widely (7).

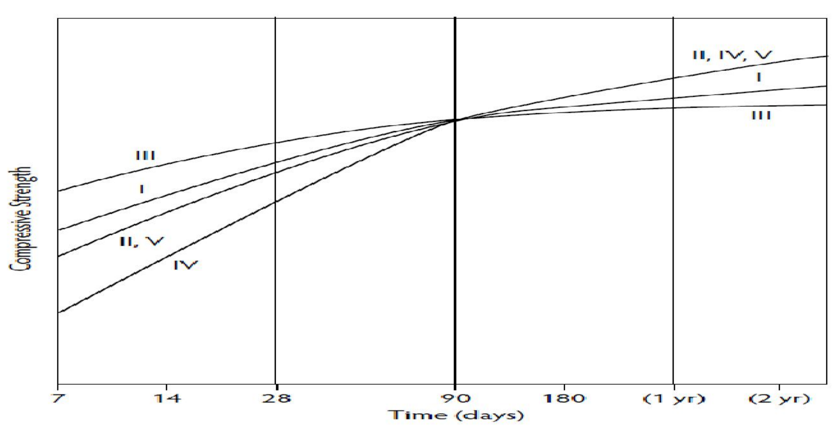

Figure 2.1: Relative compressive strengths of concretes made with different cements (7).

2.2.2 Water

Although the water itself is often not considered when dealing with materials that go into the production of concrete, it is an important ingredient. Typically, 150 to 200 kg/m3 of water is used. The old rule of thumb for water quality is "If you can drink it, you can use it in concrete," although good-quality concrete can be made with water that is not really potable. Indeed, more bad concrete is made by using too much drinkable water than by using the right amount of undrinkable water. The tolerable limits for various common impurities in mixing water are given in the table below. (7)

Impurity	Maximum Concentration (ppm)	Remarks
Suspended matter (turbidity)	2000	Silt, clay, organic matter
Algae	500–1000	Entrains air
Carbonates	1000	Decreases setting times
Bicarbonates	400–1000	400 ppm for bicarbonates of Ca or Mg
Sodium sulfate	10,000	May increase early strength but reduce later strength
Magnesium sulfate	40,000	
Sodium chloride	20,000	Decreases setting times, increases early strength,
Calcium chloride	50,000	reduces ultimate strength, and may lead to corrosion
Magnesium chloride	40,000	of reinforcing steel
Sugar	500	Affects setting behavior

Figure 2.2: Tolerable Levels of Some Impurities in Mixing Water (7)

2.2.2.1 Water cement (w/c) ratio

For ordinary concretes, the w/c ratio law works well for a given set of raw materials, because the aggregate strength is generally much greater than the paste strength; however, the w/c ratio law is more problematic for high-strength concretes, in which the strength-limiting factor may be the aggregate strength or the strength of the interfacial zone between the cement and the aggregate (7).

Although it is, of course, necessary to use very low w/c ratios to achieve very high strengths, the w/c ratio vs. strength relationship is not as straightforward as it is for normal concretes.

Figure 2.2 shows a variety of water/ cementitious material vs. strength relationships obtained by a number of different investigators. A great deal of scatter can be seen in the results. In addition, the range of strengths for a given w/c ratio increases as the w/c ratio decreases, leading to the conclusion that, for these concretes, the w/c ratio is not by itself a very good predictor of strength; a different w/c ratio "law" must be determined for each different set of materials (7).

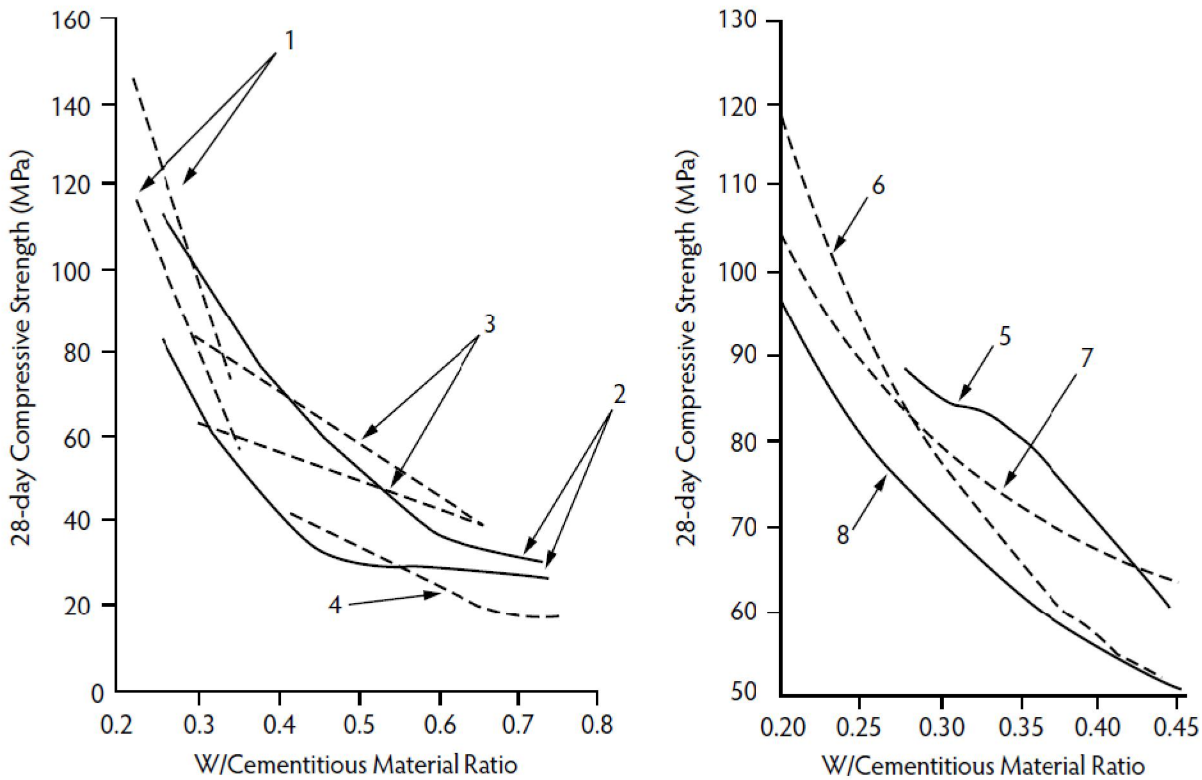

Figure 2.3: Water/cementitious material vs. strength relationships obtained by different investigators (7).

2.2.3 AGGREGATES

Aggregates make up about 75% of the volume of concrete, so their properties have a large influence on the properties of the concrete. Aggregates are granular materials, most commonly natural gravels and sands or crushed stone, although occasionally synthetic materials such as slag or expanded clays or shale are used (7).

The role of the aggregate is to provide much better dimensional stability and wear resistance; without aggregates, large castings of neat cement paste would essentially self-destruct upon drying. Also, because they are less expensive than Portland cement, aggregates lead to the production of more economical concretes. In general, aggregates are much stronger than the cement paste, so their exact mechanical properties are not considered to be of much importance (except for very high-strength concretes). For ordinary concretes, the most important aggregate properties are the particle grading (or particle-size distribution), shape, and porosity, as well as possible reactivity with the cement. All aggregates should be clean—that is, free of impurities such as salt, clay, dirt, or foreign matter (7).

The physical properties like specific gravity, porosity, thermal, and the chemical properties of an aggregate are attributed to the parent rock. However, the shape and surface texture of natural aggregates and the density, porosity, in addition to shape and surface texture in artificial aggregates are attributed from the mode of production. It is, therefore, very important to give a due consideration to the source and mode of production of aggregates. As a matter of convenience, aggregates are generally divided into two size ranges: **coarse aggregate**, which is the fraction of material retained on a No. 4 (4.75-mm) sieve, and **fine aggregate**, which is the fraction passing the No. 4 sieve but retained on a No. 100 (0.15-mm) sieve (7).

To analyze the physical properties of aggregates we have to determine the parameters corresponding to aggregate specific gravity and absorption, particle grading, aggregate moisture content, unit weight, etc.

2.2.3.2 Grading

The gradation of an aggregate is defined as the frequency of a distribution of the particle sizes of a particular aggregate. Aggregate grading can be divided into three categories: (8)

1. Coarse aggregate: material retained by No. 4 sieves.
2. Fine aggregate: material passing No. 4 sieve and retained on No. 200 sieve.
3. Micro fines: material passing No. 200 sieve.

The smaller aggregates will fill in the voids created by the larger aggregates. Larger maximum sizes of coarse aggregates are beneficial for workability because they extend the range of aggregate sizes which improves grading. Aggregate grading can be improved by combining two different grades of coarse aggregates (9).

Improving aggregate grading can help maximize aggregate content and lower cement content. Particles of irregular shape do not fit together perfectly and voids are created when these particles are assembled in a single container (9).

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; this is probably due to the angularity of the manufactured sands particle. A decrease in the workability and durability of concrete are possible consequences of using an aggregate with either an excess or a lack of a particular size fraction. One common method used for evaluating gradation of fine aggregates is by computing the fineness modulus (ASTM C 33). Fineness modulus is obtained by adding the total percentage of a fine aggregate sample retained on each of a specified series of sieves, and dividing the sum by 100 (9).

The main factors governing the desired aggregate grading are:

- The surface area of the aggregate, which determines the amount of water necessary to wet all the solids
- The relative volume occupied by the aggregate
- The workability of the mix
- The tendency to segregation.

2.2.3.3 Aggregate moisture content

Aggregates can hold water in two ways: absorbed within the aggregate porosity or held on the particle surface as a moisture film. Thus, depending on the relative humidity, recent weather conditions, and location within the aggregate stockpile, aggregate particles can have variable moisture content. For the purposes of mix proportioning, however, it is necessary to know how much water the aggregate will absorb from the mix water or how much extra water the aggregate might contribute (7).

Four different moisture states: (7)

- Oven-dry (OD)—all moisture is removed by heating the aggregates in an oven at 105°C to constant weight.
- Air-dry (AD)—no surface moisture is present, but the pores may be partially full.
- Saturated surface dry (SSD)—all pores are full, but the surface is completely dry.
- Wet—all pores are full, and a water film is on the surface.

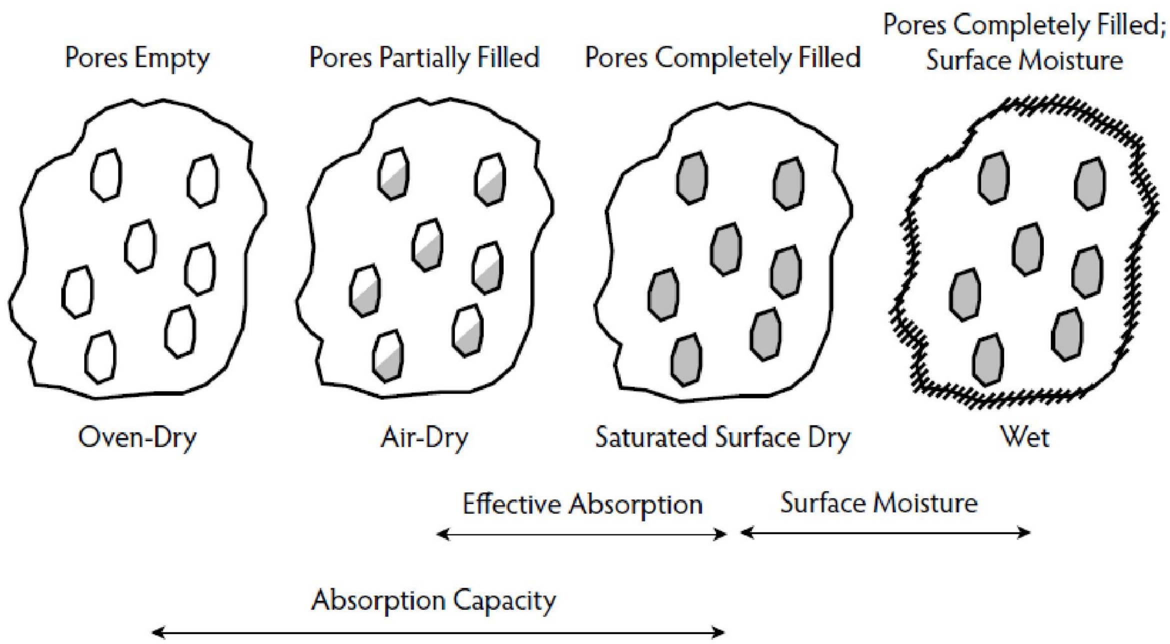

Figure 2.4: Absorption capacities of aggregates (7)

The absorption capacity (AC); represents the maximum amount of water the aggregates can absorb. This is the difference between the SSD and OD states, expressed as a percentage (7).

$$AC = \frac{W_{SSD} - W_{OD}}{W_{OD}} \times 100\% \qquad (2.1)$$

2.3 Types of Fine Aggregate

Fine aggregates can be divided in to natural and artificial fine aggregates. Natural fine aggregates can also be sub divided in to river sand and manufactured (crushed) sand. The types of some of the natural fine aggregates are briefly discussed below.

2.3.1 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 (10) .

2.3.2 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 (10).

Since the river sands are obtained from mining of river banks it has big impact on the environment and it is not sustainable resource, looking for other alternatives is the next big challenge.

Yasmin Yusuf studied fine aggregate production and its environmental impact in some selected sites of the rift valley area in Ethiopia. The results have shown that the mining of the river sand has brought about an impact on the geology (physical). Some of the impacts are the loss of the stability of the structures, the decrease in water as well as the air quality. The research has also shown that the other impacts of sand mining are the damage to roads, the use of unplanned access roads damaging the farm lands damaging their crop, diversion of the canal which caused damage to crop agriculture and humanity as well as erosion of fertile land and, siltation in the downstream areas, i.e. the Awash basin (11).

2.3.2 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 (10).

2.3.3 Manufactured sand

Manufactured sand is a purpose-made crushed fine aggregate produced from a suitable source material and designed for use in concrete. Only source materials with suitable strength, durability and shape characteristics should be considered. Production generally involves crushing, screening and possibly washing. Separation into discrete fractions, recombining and blending may be necessary (12).

Natural sand has been almost exclusively used in concrete. As the sources of natural sands are diminishing, manufactured sands have been considered as an alternative. Manufactured fine aggregates (MFA) are produced by crushing quarried stones into smaller sized aggregates. These aggregates have properties different from the natural aggregates that have been historically used. These differences in properties have led to problems involving proportioning of mixtures and the ability to obtain the fresh and hardened properties required for good quality concrete (8).

During the production processes, it is ensured that sand stockpiles are not contaminated with weathered/highly altered rock or with clay and other contaminants. Crushing of multiple source rocks into a single sand stockpile is also not be permitted unless it can be demonstrated that such a process is under blending control and produces a consistent product (13).

An experimental research carried out in India by Priyanka A. Jadhava and Dilip K. Kulkarni to investigate concrete made by partial replacement of river sand by manufactured sand using Coarse aggregate 12mm [70%] and 10mm [30%] , which was manufactured from locally available rock and the cement used was ordinary Portland cement. The percentage replacement of manufactured sand by natural sand as 0.4, 0.45, 0.5, 0.55 and 0%, 20%, 40%, 60%, 80% and 100% respectively on the strength propertied of concrete. The results were that the concrete exhibits excellent strength with 60% replacement of natural sand, so manufactured sand can be used in concrete as viable alternative to natural sand (14).

Here in Ethiopia, Sheferaw dinku assessed the influence of manufactured sand on the compressive strength development of concrete and compared the result with that of concrete produced using selected natural sand. On his study, fifteen different concrete mixes having five mix proportions for both natural and manufactured sand (i.e. 100%NS+ 0%MS; 75%NS+25%MS; 50%NS+50%MS; 25%NS+75%MS and 0%Ns+100%MS) were prepared for normal strength, intermediate strength and high strength concrete using a water cement ratio and cement contents of 0.54, 370kg/m3; 0.39, 460kg/m3; 0.30, 520kg/m3 respectively. The properties of these mixes have then been assessed both at the fresh and hardened state. In addition, comparison of costs for each concrete mixes based on the price of the concrete material collected from Addis Ababa, Nazareth, Awassa, Mekelle and Jimma towns were made (4).

And the conclusion with respect to the cost was that in the case of Addis Ababa and Jimma the purchase price of natural sand is increasing, implying that there will not be much difference between the use of manufactured and natural sand (4).

In general by using manufactured sand in partial or full replacement to natural sand, it is possible to achieve a better strength than the natural sand mix alone without significant cost variation. And the test results shown that concrete mixes with partial proportions of manufactured and natural sand achieved a higher compressive strength at all test ages (4).

Friyat negash done a study on hand crushed adigrat sandstone as a fine aggregate for cement concrete. The results of the study showed that the maximum compressive strength is found at 50% replacement of river sand, and the tensile strength decreases as the replacement of river sand by hand crushed sand Increases (15).

2.5 Properties of Fresh concrete

Fresh concrete is defined as concrete at the state when its components are fully mixed but its strength has not yet developed. The requirement of a fresh concrete is to be workable enough so that the placing and compacting of the concrete are achieved easily. Segregation and bleeding of fresh concrete also affects the strength of the hardened concrete (1).

2.5.1 Workability

Workability is a general term to describe the properties of fresh concrete. Workability is often defined as the amount of mechanical work required for full compaction of the concrete without segregation. This is a useful definition because the final strength of the concrete is largely influenced by the degree of compaction. A small increase in void content due to insufficient compaction could lead to a large decease in strength. The primary characteristics of workability are consistency (or fluidity) and cohesiveness. Consistency is used to measure the ease of flow of fresh concrete. And cohesiveness is used to describe the ability of fresh concrete to hold all ingredients together without segregation and excessive bleeding (1).

2.5.1.1 Factors affecting workability *(1)*

- Water content: Except for the absorption by particle surfaces, water must fill the spaces among particles. Additional water "lubricates" the particles by separating them with a water film. Increasing the amount of water will increase the fluidity and make concrete easy to be compacted. Indeed, the total water content is the most important parameter governing consistency. But, too much water reduces cohesiveness, leading to segregation and bleeding. With increasing water content, concrete strength is also reducing.

- Aggregate mix proportion: For a fixed w/c ratio, an increase in the aggregate/cement ratio will decrease the fluidity. Generally speaking, a higher fine aggregate/coarse aggregate ratio leads to a higher cohesiveness.
- Maximum aggregate size: For a given w/c ratio, as the maximum size of aggregate increases, the fluidity increases. This is generally due to the overall reduction in surface area of the aggregates.
- Aggregate properties: The shape and texture of aggregate particles can also affect the workability. The more nearly spherical and smoother the particles, the more workable the concrete.
- Cement: Increased fineness will reduce fluidity at a given w/c ratio, but increase cohesiveness. Under the same w/c ratio, the higher the cement content, the better the workability (as the total water content increases.

2.5.1.2 Segregation and bleeding *(1).*

- Segregation (separation): Segregation means separation of the components of fresh concrete, resulting in a non-uniform mix. More specifically, this implies some separation of the coarse aggregate from mortar.
- Bleeding (water concentration): Bleeding means the concentration of water at certain portions of the concrete. The locations with increased water concentration are concrete

surface, bottom of large aggregate and bottom of reinforcing steel. Bleed water trapped under aggregates or steel lead to the formation of weak and porous zones, within which micro cracks can easily form and propagate.

2.5.2 Placing, Compacting and Curing

Concrete should be placed as close to its final position as possible. To minimize segregation, it should not be moved over too long a distance. After concrete is placed in the formwork, it has to be compacted to remove entrapped air. Compaction can be carried out by hand rodding or tamping, or by the use of mechanical vibrators (1).

For concrete to develop strength, the chemical reactions need to proceed continuously. Curing refers to procedures for the maintaining of a proper environment for the hydration reactions to proceed. It is therefore very important for the production of strong, durable and watertight concrete. In concrete curing, the critical thing is to provide sufficient water to the concrete, so the chemical reaction will not stop. Moist curing is provided by water spraying, ponding or covering the concrete surface with wet sand, plastic sheets, burlaps or mats (1).

2.5.3 Measurement of workability

The workability of concrete can be measured by using different test methods. The most commonly used method is slump test. The test procedure is given in American standard (ASTM C143) (16).

Three different kinds of possible slumps exist, true slump, shear slump, and collapse slump. Conventionally, when shear or collapse slump occur, the test is considered invalid. Concrete mix proportions shall be such that the concrete is of adequate workability and can properly be compacted (9). In this research the true slump will be used as the parameter to indicate the workability of the concrete.

2.6 Mix Design

Mix design is the process of determining required and specifiable characteristics of a concrete mixture (9).

Basic Considerations in mix design (17).

- Economy**:** The material costs are most important in determining the relative costs of different mixes. The labor and equipment costs, except for special concretes, are generally independent for the mix design. Since cement is more expensive than aggregate, it is clear that cement content should be minimized.
- Workability**:** A good mix design must be capable of being placed and compacted, with minimal bleeding and segregation, and be finishable. Water requirements depend on the aggregate rather than the cement characteristics. Workability should be improved by redesigning the mortar faction rather than simply adding more water.
- Strength and Durability**:** In general, the minimum compressive strength and a range of w/c ratios are specified for a given concrete mix. Possible requirements for resistance to freeze-thaw and chemical attack must be considered. Therefore, a balance or compromise must be made between strength and workability.

2.6.1 Mix proportioning

Mix proportioning is the process of determining the quantities of concrete ingredients that meet the mix design criteria.

The primary considerations in mix proportioning include: (9)

- The ability to continually meet or exceed specifications (durability and strength).
- Economy.
- Readily available supply of raw materials.

The step by step procedures for proportioning the mix to determine the desired strength, workability and economy for the end product concrete are given in the ACI code and the mix should be proportioned accordingly.

2.7 Strength of hardened concrete

Strength is defined as the ability of a material to resist stress without failure. The failure of concrete is due to cracking. Under direct tension, concrete failure is due to the propagation of a single major crack. In compression, failure involves the propagation of a large number of cracks, leading to a mode of disintegration commonly referred to as 'crushing'. The strength is the property generally specified in construction design and quality control, for the following reasons: (1)

- it is relatively easy to measure, and
- Other properties are related to the strength and can be deduced from strength data.

The 28-day compressive strength of concrete determined by a standard uniaxial compression test is accepted universally as a general index of concrete strength (1).

2.7.1 Specimen standards for compressive and tensile concrete strength test

1 Specimen for compressive strength determination

The cube specimen is popular in U.K. and Europe while the cylinder specimen is commonly used in the U.S. The Ethiopian standard (EBCS-2) states that cube specimen with 150 mm dimension shall be used for compression tests on concrete.

I. Cube specimen BS 1881: Part 108: 1983. Filling in 3 layers with 50 mm for each layer (2 layers for 100 mm cube). Strokes 35 times for 150 mm cube and 25 times for 100 mm cube. Curing at 20±5 ^{0}C and 90% relative humility (18).

II. Cylinder specimen ASTM C470-81. Standard cylinder size is 150 x 300 mm. Curing condition is temperature of 23±1.7 ^{0}C and moist condition. Grinding or capping is needed to provide level and smooth compression surface (19).

2 Specimen for tensile strength determination

a) Direct tension test methods

   Direct tension tests of concrete are seldom carried out because it is very difficult to control. Also, perfect alignment is difficult to ensure and the specimen holding devices introduce secondary stress that cannot be ignored. In practice, it is common to carry out the splitting tensile test or flexural test.

b) Indirect tension test (split cylinder test or Brazilian test)

   i) BS 1881: Part 117:1983. Specimen 150 x 300 mm cylinder. Loading rate 0.02 to 0.04 MPa/s (20).
   ii) Cylindrical Specimens—Cylinders for such tests as compressive strength, Young's modulus of elasticity, creep, and splitting tensile strength may be of various sizes with a minimum of 2-in. [50-mm] diameter by 4-in. [100-mm] length. Where correlation or comparison with field-made cylinders (Practice C 31/C 31M) is desired, the cylinders shall be 6 by 12in. [or 150 by 300 mm] (19).

The splitting test is carried out by applying compression loads along two axial lines that are diametrically opposite. This test is based on the following observation from elastic analysis. Under vertical loading acting on the two ends of the vertical diametrical line, uniform tension is introduced along the central part of the specimen (20).

Chapter 3 METHODOLOGY

3.1 Study area

Although construction of structures by using concrete is widely spread throughout the country, this research was concentrating only on Jimma town and on the materials available in and around Jimma.

The source rock of the manufactured sand is basaltic igneous rock and samples are taken from Rama construction quarry which is found in Jimma city at Kito Furdissa. Rama construction quarry already had some history of product supply for concrete production for other construction firms and for its own construction sites. Although there is one another crushing factory in Jimma city the production control is poor and lots of clay lump is seen on the source rock so it is not chosen compared with the Rama construction quarry's crushed rock.

The manufactured sand is not produced purposefully for use in concrete instead it is a by-product of the coarse aggregate crushing process. These is because the crushing factory of Rama construction is mainly producing coarse aggregates for concrete and road construction but on the process of producing the coarse aggregates there is a by-product of small fines which is collected and stock piled at specific places. These fines are used mostly for plastering purpose and at some conditions used for pavement finish and concrete productions.

Figure 3.2 Crushed rock in Rama crushing factory

Figure 3.1 Basaltic igneous rock used to produce aggregates in Jimma

The rationale for taking this sample from this source was that if the manufactured sand was being produced purposefully for concrete production then the manufactured sand would have been acceptable sand for use.

Due to wide availability on the study area the Dangote PPC was used for the preparation of the mix for C- 25 and C-30 concrete grades. All the physical properties of the cement were taken from the manufacturer.

PPC or Portland pozzolana cements are blends of Portland cement and a pozzolanic material. The role of the pozzolan is to react slowly with the calcium hydroxide that is liberated during cement hydration. This tends to reduce the heat of hydration and the early strength but can increase the ultimate strength of the material.

Natural sand in Jimma town are brought from the neighboring towns like the Asendabo river sand or brought from as far as Silte zone the Werabe river sand. As some contractors suggests, due to the higher silt contents and impurities, the above mentioned sand are not suitable to be used for normal strength concrete.

The most widely used sand type in Jimma area for construction purpose is the Gambela river sand. And by visual inspection it can be seen that the Gambela river sand is cleaner or contains lesser silt content compared to the other sources.

It should be noted that if the manufactured sand had to be compared with river sand it should be with the best river sand on the area otherwise it cannot be taken as alternative fine aggregate for the production of concrete.

And taking more than one river sand sample would result in doubling of the sample size prepared. Due to the five percentage replacement of the manufactured sand and the two concrete grade type used in this study, the sample size is large which takes lots of time and cost.

Due to the above mention reasons the natural sand sample was taken from the most widely used sand type in Jimma area which is brought from the Gambela river sand.

3.2 Study design

The study is designed to suit the raised research topic which is applied type of research. The first part of the research report is the literature review which assists in having a clear understanding of the subject matter as well as in identifying what problems exist in the study area.

As the research is an applied type of research, the main source of data is primary data which is found from the testing process by directly recording the test results and findings. And it is possible to determine representative results by analyzing the sample test results.

The final part is reporting of the experimental results which are organized into two sections. First, attention is given to the summary of physical properties of the aggregate samples and determining the mix proportions of concrete. Next, the test results are analyzed, discussed and illustrated.

3.3 Sampling technique

The sampling technique applied in this research was the proportioned stratified sampling. This sampling technique is chosen because of the stratified population in the sampling groups which is categorized in to two groups based on the two main fine aggregate types found in Jimma (natural sand and manufactured sand). Equal proportion should be given for both sand types due to the unknown material properties and to conduct same type of experiment on both of the sand types.

Initially Samples will be taken from selected natural and manufactured sand and checked if they can satisfy physical requirements namely, silt content, density of the aggregates, gradation, water absorption and specific gravity set by different standards. Afterwards five combinations of natural and manufactured sand at an interval of 25% replacement (i.e. 100 NS +0 MS, 75 NS + 25 MS, 50NS + 50MS, 25NS + 75MS and 0NS+100 MS) will be prepared for C-25 and C-30 grade concrete (17).

Then the mix design of the concrete grades are calculated by using the ACI mix design methods and adjusted by trial batch mix. After the mix proportions are determined the concrete cube samples are prepared and cured for the specified days to do the compressive and tensile strength tests and measurement of the failure loads on the concrete sample.

3.4 sample size

The combination of river and manufactured sand at 25% interval gives five samples of cube concrete. A total of 30 samples each 15 samples are to be crushed at the 7th and 28th day which can give the full compressive strength of the concrete sample. The remaining 15 cylindrical sample are for split tensile test which is to be tested at 28th day. The test sample size is given in the table below.

Table 3.1 Sample size

M.S replacement	Concrete grade	Concrete test type	Concrete specimens		Total samples
			7th day	28th day	
100% M.S	C-25	Compressive strength	3	3	6
75% M.S	C-25	Compressive strength	3	3	6
50% M.S	C-25	Compressive strength	3	3	6
25% M.S	C-25	Compressive strength	3	3	6
0% M.S	C-25	Compressive strength	3	3	6
100% M.S	C-25	Tensile strength	-	3	3
75% M.S	C-25	Tensile strength	-	3	3
50% M.S	C-25	Tensile strength	-	3	3
25% M.S	C-25	Tensile strength	-	3	3
0% M.S	C-25	Tensile strength	-	3	3
100% M.S	C-30	Compressive strength	3	3	6
75% M.S	C-30	Compressive strength	3	3	6
50% M.S	C-30	Compressive strength	3	3	6
25% M.S	C-30	Compressive strength	3	3	6
0% M.S	C-30	Compressive strength	3	3	6
SUM					**75**

3.5 Test experiment

The test experiment was done in Jimma institute of technology at the laboratory of civil engineering department. The main test experiment which have been done and has a major impact on the compressive strength of the concrete are discussed as follows.

1. Gradation

Particle size distribution, or grading, is one of the most influential and commonly reported characteristics of an aggregate. Numerous research papers and design methods demonstrate how grading influences concrete durability, porosity, workability, cement and water requirements, strength and shrinkage. The ASTM specifications permit the minimum percentages (by mass) of material passing the 300µm (No.50) and 150µm (No. 100) sieves to be reduced to 5% and 0% respectively, provided.

Table 3.2 Fine aggregate grading limits (ASTM C 136)

Sieve size	**Percentage passing**
9.50mm (3/8 in.)	100
4.75mm (No. 4)	95 – 100
2.36mm (No. 8)	80 – 100
1.18mm (No. 16)	50 – 85
600µm (No. 30)	25 – 60
300µm (No. 50)	5 – 30
150µm (No. 100)	0 – 10

2. Specific gravity and Water Absorption

The specific gravity and Water Absorption is a definitive measure of fine aggregate density and water absorption; it is used to determine the key design parameters for concrete mixes and therefore it is a highly relevant property of both natural and manufactured sands. The specific gravity shows the void in the concrete or compactness and the amount of water that is held within those voids is calculated and reported as the Water Absorption of the material.

3. Moisture content

It is well known fact that the water – cement ratio affects the workability and strength of concrete. A design water – cement ratio is usually specified based on the assumption that the aggregates are inert but in most cases aggregates from different sources do not comply with this, wet aggregate will give water to the mix and dry aggregate will take water from the mix affecting the design water cement ratio. In order to correct this discrepancies the moisture content should be determined.

4. Silt content

Silt content affects the workability of the mix by absorbing water and creates less adhesive property with the cement which intern results in weaker bond strength and pure quality of concrete.

The laboratory method is used to determine the silt contents of the aggregates. If the silt content is greater than 6% of the total mass the sand should not be used unless it is washed properly.

5. Workability

Workability is generally defined in terms of the amount of mechanical work, or energy, required to produce full compaction of the concrete without segregation, since the final strength of the concrete is in large part a function of the amount of compaction. Workability of mixed concrete on the fresh state can be determined by using slump test or compaction factor.

In this study the slump test was used to describe the workability of the concrete. The method used to determine the slump was by using slump cone test. The slump value and workability of the concrete is related and shown in the table below.

Table 3.3 Values of workability for different placing conditions (7)

Degree of workability	consistency	Slump (mm)	Compaction factor	Uses
Extremely low	Moist earth	0	0.65-0.7	Pre cast paving slab
Very low	Very dry	0-25	0.7-0.8	Roads (power vibrated) vibrated concrete in walls or other large sections
Low	Dry	25-50	0.8-0.85	Mass concreting(w/o vibration), light reinforced section (with vibration) and roads (hand vibrator
Medium	plastic	50-100	0.85-0.95	Flat slabs, heavily reinforced sections (manual vibrator)
High	Semi-fluid	100-175	0.95-1.0	RCC with congested reinforcement(cannot be vibrated)

6. Compressive strength

Compression test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. The compressive strength of concrete was determined using 150mm concrete cubes. The concrete was made by replacing at an interval of 25% replacement of the natural sand by manufactured sand.

Compressive strength was measured on a universal testing machine at 7th and 28th day from the first day of preparation for both C-25 and C-30 concrete grades.

Figure 3.3 Compressive strength test

7. Tensile strength

Concrete as we know is relatively strong in compression and weak in tension. In reinforced concrete members, little dependence is placed on the tensile strength of concrete since steel reinforcing bars are provided to resist all tensile forces. However, tensile stresses are likely to develop in concrete due to drying shrinkage, rusting of steel reinforcement, temperature gradients and many other reasons. Therefore, the knowledge of tensile strength of concrete is of importance.

The tensile strength was determined by using splitting test. This test is done on cylindrical specimens of dia. 200 mm and100mm lengths.

The tensile strength was measured on universal testing machine at 28^{th} day from the first day of preparation for C-25 concrete grade.

Figure 3.4 Split testing of cylindrical concrete

Chapter 4 PHYSICAL PROPERTIES, MIX PROPORTIONS AND TEST RESULTS

4.1 Physical properties

It is necessary and worthwhile to determine the physical properties of aggregates in order to design and make a concrete mix. In order to do this a number of tests were carried out on the aggregates. The performed test includes: silt content, sieve analysis, moisture content, absorption capacity and unit weight. All of the aggregates tests were done in accordance with the Ethiopian standards and conforms to the ASTM requirements.

4.1.1 Fine aggregates

The tests made on the fine aggregates were as follows.

1 Silt content

Silt is unnecessary part of sand with diameter less than 75ηm (0.075mm). If there is too much silt, the aggregate will have less adhesive property with cement resulting in weaker bond strength.

The test method applied to determine the silt content is the laboratory method and the test results are given in the table below.

Table 4.1: Silt contents of natural sand and manufactured sand

Description	Natural sand				Manufactured sand			
	Sample 1	Sample 2	Sample 3	Average	Sample 1	Sample 2	Sample 3	Average
M1 (kg)	1	1	1		1	1	1	
M2 (kg)	0.99	0.99	0.99		0.97	0.98	0.98	
Silt content (%)	0.5%	0.3%	0.5%	**0.43%**	2.5%	2%	2.2%	**2.23%**

$$\text{Silt content } \% = \frac{M_1 - M_2}{M_1} \times 100 \tag{4.2}$$

Where M_1= the original dry mass

M_2= oven dry mass after washing

2 <u>Moisture content</u>

To determine the moisture content of the fine aggregates 500g sample is taken and dried in the oven for 24 hours with a temperature of 110^{0}c. Then the sample is removed from the oven and allowed to cool for about an hour and finally the mass is measured. The result is given below

$$\% \text{ Moisture content} = \frac{M_1 - M_2}{M_1} \times 100 \tag{4.1}$$

Where

M_1= weight of original sample

M_2= weight of oven dry sample

Table 4.2: Moisture contents of natural and manufactured sand

Description	**Natural sand**				**Manufactured sand**			
	Sample 1	Sample 2	Sample 3	Average	Sample 1	Sample 2	Sample 3	Average
M1 (kg)	0.5	0.5	0.5		0.5	0.5	0.5	
M2 (kg)	0.49	0.5	0.5		0.49	0.49	0.49	
Moisture content (%)	2.04%	0%	0%	**0.68%**	2.04%	2.04%	2..04%	**2.04%**

3 Specific gravity and water absorption

For producing concrete that consistently achieves the specified or targeted strength. The fundamental relationship between water-to-cement ratio and strength starts with correcting for the moisture contribution or absorption by the aggregates. Aggregates are somewhat like small, hard sponges. Mix design calculations are conducted assuming aggregates are in a saturated surface dry (SSD) condition, meaning their absorption is satisfied and no water is taken from or added to the mix. If their absorption is not satisfied, these "sponges" steal water from the designated quantity of mix water, reducing the slump of the concrete. If the "sponges" are excessively wet (beyond that amount to satisfy the absorption), the extra water must be subtracted from the quantity of batched mix water. Otherwise, the target w/c ratio is exceeded and strengths will decrease.

To determine the specific gravity and water absorption, first we have to spread the fine aggregate sample on flat surface exposed to warm air and stir frequently to have uniform drying. Then by placing the portion of the sample loosely on a cone mold with large diameter at the bottom and by lightly tamping 25 times with a tamper and lifting the cone vertically we can determine if it has reached surface dry condition. If it slumps slightly this indicates that the sample has reached surface dry condition.

Then three 500g of surface dry fine aggregate samples are measured and immediately introduced in to the prepared pycnometer. Then filling the pycnometer with water up to 90% of the volume and removing the air voids of the sample by rolling, inverting and agitating the pycnometer. After removing all the bubbles fill the pycnometer with water to its full capacity and measure the mass, then remove the fine aggregate from the pycnometer, dry it on the oven for 1hour with a temperature of 110℃ and measure the mass and finally fill the pycnometer with water and measure the mass. The results are given on the table below.

Table 4.3: Specific gravity and absorption capacity of natural and manufactured sand

Description	Natural sand				Manufactured sand			
	sample 1	sample 2	sample 3	average	sample 1	sample 2	sample 3	Average
Mass of surface dry sample (g)	500	500	500		500	500	500	
Mass of oven dry sample in air (g)	499	499	499.5		490	490	490	
Mass of pycnometer filled with water (g)	1560	1560	1560		1560	1560	1560	
Mass of pycnometer + sample+water (g)	1875	1865	1875		1860	1865	1865	
Bulk specific gravity	2.697	2.558	2.7	2.652	2.45	2.512	2.512	2.491
Bulk specific gravity(SSD basis)	2.702	2.564	2.702	2.656	2.5	2.564	2.564	2.542
Apparent specific gravity	2.711	2.572	2.707	2.663	2.578	2.648	2.648	2.625
Absorption %	0.200	0.200	0.100	0.166	2.040	2.040	2.040	2.040

4 Gradation

To find the gradation of fine aggregate, first assemble appropriate sieve sizes with receiver at the bottom in increasing aperture size from bottom to top. Then place the sample in the sieves then shaked using mechanical sieve shaker and then weight the material retained on each sieve and the results are shown in the table below.

Table 4.4: Sieve analysis result for natural sand

sieve size (mm)	mass retained (kg)	mass retained %	cumulative retained %	cumulative passing %
9.5	0	0	0	100
4.75	0.025	1.25	1.25	98.75
2.36	0.15	7.5	8.75	91.25
1.18	0.305	15.25	24	76
0.6	0.685	34.25	58.25	41.75
0.3	0.435	21.75	80	20
0.15	0.34	17	97	3
fineness modules (FM)			2.6925	

Table 4.5: Sieve analysis result for manufactured sand

sieve size (mm)	mass retained (kg)	mass retained %	cumulative retained %	cumulative passing %
9.5	0	0	0	100
4.75	0.05	2.5	2.5	97.5
2.36	0.655	32.75	35.25	64.75
1.18	0.39	19.5	54.75	45.25
0.6	0.365	18.25	73	27
0.3	0.14	7	80	20

0.15	0.2	10	90	10
Fineness modules (FM)			3.355	

5 <u>Unit weight</u>

The unit weight of fine aggregate was determined using the following procedure. First place three layers of oven dry fine aggregate in a container of known volume and rod each layer 25 times and then level the surface using the rod and then measure the weight of the aggregate inside the container and the results are presented in the table below.

Table 4.6: Unit weight of natural sand

Description	Sample 1	Sample 2	Sample 3	Average
Mass of mould(Kg)	1.060	1.060	1.060	
Mass of mould +sand(Kg)	9.215	9.543	9.356	
Mass of sand (Kg)	8.155	8.483	8.296	
Volume of mould(m^3)	0.005	0.005	0.005	
Unit weight(Kg/m^3)	1631	1696.6	1659.2	1662.26

Table 4.7: Unit weight of manufactured sand

Description	Sample 1	Sample 2	Sample 3	Average
Mass of mould(Kg)	1.060	1.060	1.060	
Mass of mould +sand(Kg)	9.81	9.72	9.983	
Mass of sand (Kg)	8.75	8.66	8.923	
Volume of mould(m^3)	0.005	0.005	0.005	
Unit weight(Kg/m^3)	1750	1732	1784.6	1755.33

4.1.3 Coarse aggregate

The tests made on coarse aggregate are given hereafter.

1 Nominal maximum aggregate size

The nominal maximum aggregate size was determined from the sieve analysis using the principle of smallest sieve opening through which the entire amount of aggregate is permitted to pass is the nominal maximum aggregate size. From the sieve analysis the nominal maximum aggregate size is found to be 25 mm.

2 <u>Moisture content</u>

To determine the moisture content of the fine aggregates 2kg sample is taken and dried in the oven for 24 hours with a temperature of 110^0c. Then the sample is removed from the oven and allowed to cool for about an hour and finally the mass is measured. The result is given below

$$\% \text{ Moisture content} = \frac{M_1 - M_2}{M_1} \times 100 \qquad (4.2)$$

Where

M1= weight of original sample

M2= weight of oven dry sample

Table 4.8: moisture content of coarse aggregate

Description	Coarse aggregate			
	Sample 1	Sample 2	Sample 3	Average
M1 (kg)	2	2	2	
M2 (kg)	1.99	1.98	1.990	
Moisture content (%)	0.5%	1.01%	0.5%	**0.670%**

3 Unit weight

The unit weight of coarse aggregate was determined using the following procedure. First place three layers of oven dry fine aggregate in a container of known volume and rod each layer 25 times and then level the surface using the rod and then measure the weight of the aggregate inside the container and the results are presented in the table below.

Table 4.9: Unit weight of coarse aggregate

Description	Sample 1	Sample 2	Sample 3	Average
Mass of mould(Kg)	1.700	1.700	1.700	
Mass of mould +sand(Kg)	18.355	18.442	18.45	
Mass of sand (Kg)	16.655	16.742	16.75	
Volume of mould(m^3)	0.01	0.01	0.01	
Unit weight(Kg/m^3)	1665.5	1674.2	1675	1671.56

4 Specific gravity and water absorption

To fine the specific gravity and observation of fine aggregate the following activities was under taken, First place the test sample in wire basket and immerse it in water for 24 hours. Then weigh the basket with the sample in water. Then empty the aggregate on a dry cloth and return the empty basket to the water and then weight it in water. Then place the aggregate on dry cloth and gently surface dry it with the cloth then air dry the aggregate and weight it and then place the aggregate in oven dry and then weight it again and the results are shown below.

Table 4.10: Specific gravity and absorption capacity of coarse aggregate

Description	Coarse aggregate			
	Sample 1	Sample 2	Sample 3	Average
Mass of the saturated aggregate (Kg)	1.1	1.1	1.15	
Mass of saturated surface dry aggregate (Kg)	1.995	2.005	2.020	
Mass of oven dried aggregate (Kg)	1.99	1.98	1.990	
Apparent specific gravity	2.235	2.25	2.235	**2.24**
Bulk specific gravity (oven dry basis)	2.212	2.187	2.163	**2.187**
Bulk specific gravity (saturated surface dry basis)	2.333	2.215	2.195	**2.247**
Water absorption %	0.25	1.262	1.50	**1.004**

5 Gradation

To find the gradation of coarse aggregate first assemble appropriate sieve sizes with receiver at the bottom in increasing aperture size from bottom to top. Then place the sample in the sieves and shake using mechanical sieve shaker finally weight the material retained on each sieve and the results are shown in the following table.

Table 4.11: Sieve analysis result for coarse aggregate

sieve size (mm)	mass retained (kg)	mass retained %	cumulative retained %	cumulative passing %
37.5	0	0	0	100
19	6.83	68.30	68.3	31.7
9.5	0.165	1.65	98.5	0.15
4.75	0.015	0.15	100	0
2.36	0	0	100	0
1.18	0	0	100	0
0.6	0	0	100	0
0.3	0	0	100	0
0.15	0	0	100	0
fines modules			**7.67**	

4.2 Mix proportion

4.2.1 Trial mix design

In order to analyze the effects of manufactured sand, natural sand or a combination of both have on the properties of concrete, different mixes with normal strength (C-25) and intermediate strength (C-30) were prepared.

In order to determine the trial mix proportion of the concrete samples ACI mix design method was used. The procedures are given hereafter and all the tables are taken from ACI mix design code.

1. Slump

Table 4.12 Slumps for different type of construction (17)

Concrete construction	Slump, mm	
	Maximum	Minimum
Reinforced foundation Walls and footings	75	25
Plain footings, caissons, and Substructure walls	75	25
Beams and reinforced walls	100	25
Building columns	100	25
Pavements and slabs	75	25
Mass concrete	75	25

From the table the maximum slump is found to be 100mm and minimum slump 25mm

2) Maximum aggregate size

The nominal maximum size of coarse aggregate = 25mm

3. Estimation of mixing water and air content

The concrete used in this research is non air entrained concrete. The table given below shows the water required for non air entrained concrete.

Table 4.13 Approximate amount of water and air for non – air – entrained concrete (17)

NON-AIR-ENTRAINED CONCRETE								
Approximate mixing water (kg/m^3) for indicated nominal maximum sizes of aggregate								
Slump (mm)	9.5 mm	12.5 mm	19 mm	25 mm	37.5 mm	50 mm	75 mm	150 mm
25 to 50	207	199	190	179	166	154	130	113
75 to 100	228	216	205	193	181	169	145	124
150 to 175	243	228	216	202	190	178	160	-
More than 175	-	-	-	-	-	-	-	-
Approximate amount of entrapped air in non-air-entrained concrete (%)								
Slump (mm)	9.5 mm	12.5 mm	19 mm	25 mm	37.5 mm	50 mm	75 mm	150 mm
All	3.0	2.5	2.0	1.5	1.0	0.5	0.3	0.2

From the table the weight of the water required for the trial mix is = 193kg/m^3

And air content = 1.5%

4. Water cement ratio

Table 4.14 Relationship between water cement ratio and compressive strength (17)

Relationship between water –cement or water – cementitious materials ratio and compressive strength of concrete	
Compressive strength at 28 days (MPa)	Water –cement ratio by weight (Non-air-entrained concrete)
40	0.42
35	0.47

30	0.54
25	0.61
20	0.69
15	0.79

From the above table for C-25 w/c = 0.61 and for C-30 w/c = 0.54

5. Calculation of cement content

Once the water cement ratio and the weight of the water per cubic meter are determined the cement content can be calculated easily.

Weight of cement = weight of water/water cement ratio

For C-25 Weight of cement = 193 kg/m^3/0.61 = 316.393 kg/m^3

For C-30 weight of cement = 193 kg/m^3/0.54 = 357.407 kg/m^3

6. Estimation of coarse aggregate content

The percent of coarse aggregate to concrete for a given maximum size and fineness modulus is given by Table below.

Table 4.15 Volume of oven dry coarse aggregate for different fineness modules (17)

Volume of oven-dry-rodded coarse aggregate per unit volume for different fineness moduli of fine aggregate				
Nominal maximum size of aggregate (mm)	2.4	2.6	2.8	3.00
9.5	0.50	0.48	0.46	0.44
12.5	0.59	0.57	0.55	0.53
19	0.66	0.64	0.62	0.60
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	0.80	0.78	0.76
150	0.87	0.85	0.83	0.81

From the table for the fineness modules of 2.69 and maximum aggregate size 25 mm

The coarse aggregate per unit volume = 0.68

Unit weight of aggregate = 1671.56 kg/m^3

Weight of coarse aggregate = 1671.56 kg/m^3 x 0.68 = 1136.66 kg

7. Estimation of fine aggregate content

There are two standard methods to establish the fine aggregate content, the mass method and the volume method. The volume method has been used.

Volume of water = $\frac{193}{1000} = 0.193$ m^3

Volume of cement (C-25) = $\frac{316.393}{2.9\times1000} = 0.109$ m^3

Volume of cement (C-30) = $\frac{35\ 74\ 07}{2.9\times1000} = 0.123$ m^3

Volume of coarse aggregate = $\frac{1136.66}{2.4\ 7\times1000} = 0.460$ m^3

Volume of air = 0.01 m^3

Total volume (C-25) = 0.772 m^3 Total volume (C-30) = 0.786 m^3

Volume fine aggregate (C-25) = 1- 0.772 = 0.228 m^3

Volume fine aggregate (C-30) = 1- 0.786 = 0.214 m^3

Weight of fine aggregate (C-25) = 2.542 x 1000 x 0.228 = 579.576 kg

Weight of fine aggregate (C-30) = 2.542 x 1000 x 0.214 = 543.988 kg

8. Adjustment for moisture in aggregate

Design mix water = 193 lit.

Total moisture content in coarse aggregate = 0.67%

Total moisture content in fine aggregate = 0.68%

The degree of moisture absorption of coarse aggregate = 1%

The degree of moisture absorption of fine aggregate = 2.04%

Net mix water = 204.65 lit.

Wet weight of coarse aggregate = 1143.611 kg/m^3

Table 4.16: Trial mix proportion summary

Concrete class	Fine aggregate type	Cement Type	Cement (kg/m^3)	W/C ratio	Water (lit.)	Fine aggregate(kg/m^3)	Coarse aggregate(kg/m^3)
C-25	100% Natural sand	PPC	316.393	0.61	204.65	579.576	1143.611
C-30	100% Natural sand	PPC	357.407	0.54	204.65	543.988	1143.611

4.2.2 Final mix design

Using the proportions developed in the preceding steps; a trial batch of concrete is mixed using only as much water as is needed to reach the desired slump (but not exceeding the permissible w/c ratio). The fresh concrete should be tested for slump, unit weight, yield, air content, and its tendencies to segregate, bleed, and finishing characteristics. Also, hardened samples should be tested for compressive and tensile strength. After doing all this, the final mix proportion is found and presented in the table below.

Table 4.17: Final mix proportion summery

Concrete class	Fine aggregate type	Cement Type	Cement (kg/m^3)	W/C ratio	Water (lit.)	Fine aggregate(kg/m^3)	Coarse aggregate(kg/m^3)
C-25	100% N.S	PPC	360	0.54	205	545	1144
C-30	100% N.S	PPC	411	0.47	205	480	1144

4.3 Preparation of specimens and mixing procedure

Cement, which were produced locally by Dangote cement factory, were used throughout the mixing process. Dangote Portland pozzolana cement for normal strength concrete and Intermediate concrete were used.

The preparation of the constituent materials was made by using weight measurement. After determining the relative amounts of materials to be used for specimens, the aggregates and cements were mixed dry for one minute.

After the addition of water, all the material mixed for another two minutes. Immediately after mixing the concrete, the workability is measured by using a slump cone.

Figure 4.1: Slump cone test

The specimens were then put on prepared mould by compacting in three layers by tamping 35 times with a tamping rod after placing each layer . After compaction the top surface is finished using a trowel.

Figure 4.2: Surface finished specimens

After 24 hours the concrete specimens are taken out of mould.

Figure 4.3: Produced concrete samples

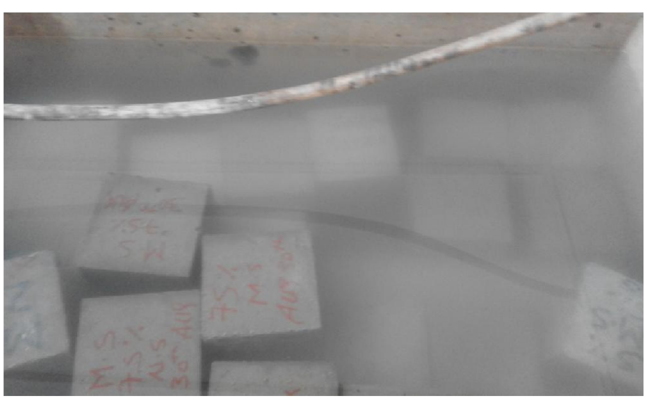

Figure 4.4: Curing in water tanker

Then the concrete specimens were cured using immersion in water tanker for 7 and 28 days for each proportion and each concrete grade (C-25 and C-30).

4.4 Test results

4.4.1Compressive strength

The cube specimens were taken out of the curing water tank for compressive strength test at the age of 7th and 28th day.

The results at 7th and 28th day for both C-25 and C-30 concrete grades are shown in the tables below.

Table 4.18: 7th day compressive strength (C-25)

Fine aggregate	weight (kg)	Density(Kg/m3)		crushing load(KN)	compressive strength(Mpa)	
		Individual	Average		individual	Average
100% N.S	8.530	2527.407	2524.444	401.000	17.822	17.393
	8.430	2497.778		387.290	17.213	
	8.600	2548.148		385.770	17.145	
75% N.S & 25% M.S	8.100	2400.000	2528.395	455.330	20.237	18.635
	8.900	2637.037		390.240	17.344	
	8.600	2548.148		412.320	18.325	
50% N.S & 50% M.S	8.330	2468.148	2508.642	425.010	18.889	19.530
	8.730	2586.667		459.620	20.428	
	8.340	2471.111		433.670	19.274	
25% N.S & 75% M.S	8.110	2402.963	2480.988	355.350	15.793	16.838
	8.110	2402.963		369.010	16.400	
	8.900	2637.037		412.230	18.321	
100% M.S	8.700	2577.778	2535.802	389.800	17.324	18.571
	8.435	2499.259		440.540	19.580	
	8.540	2530.370		423.230	18.810	

Table 4.19: 7th day compressive strength (C-30)

Fine aggregate	weight (kg)	Density(Kg/m3)		crushing load(KN)	compressive strength (Mpa)	
		Individual	Average		Individual	Average
100% N.S	7.410	2195.556	2398.519	419.100	18.627	22.276
	8.405	2490.370		556.400	24.729	
	8.470	2509.630		528.100	23.471	
75% N.S & 25% M.S	8.300	2459.259	2469.630	455.000	20.222	21.378
	8.505	2520.000		502.300	22.324	
	8.200	2429.630		485.700	21.587	
50% N.S & 50% M.S	8.190	2426.667	2440.494	571.200	25.387	25.353
	8.120	2405.926		558.900	24.840	
	8.400	2488.889		581.200	25.831	
25% N.S & 75% M.S	8.330	2468.148	2543.210	370.500	16.467	21.212
	8.320	2465.185		519.700	23.098	
	9.100	2696.296		541.600	24.071	
100% M.S	7.925	2348.148	2378.272	450.400	20.009	20.001
	7.925	2348.148		440.700	19.587	
	8.230	2438.519		461.400	20.507	

Table 4.20: 28th day compressive strength (C-25)

Fine aggregate	weight (kg)	Density(Kg/m3)		crushing load(KN)	compresive strength(Mpa)	
		Individual	Average		individual	Average
100% N.S	8.210	2432.593	2439.012	532.000	23.644	23.239
	8.410	2491.852		543.460	24.154	
	8.075	2392.593		493.150	21.918	
75% N.S & 25% M.S	8.485	2514.074	2527.901	643.900	28.618	29.920
	8.455	2505.185		735.000	32.667	
	8.655	2564.444		640.700	28.476	
50% N.S & 50% M.S	8.125	2407.407	2467.16	664.200	29.520	31.573
	8.390	2485.926		764.100	33.960	
	8.465	2508.148		702.900	31.240	
25% N.S & 75% M.S	8.570	2539.259	2495.309	679.500	30.200	29.757
	8.195	2428.148		629.800	27.991	
	8.500	2518.519		699.300	31.080	
100% M.S	8.125	2407.407	2437.531	704.900	31.329	29.413
	8.155	2416.296		612.300	27.213	
	8.400	2488.889		668.200	29.698	

Table 4.21: 28th day compressive strength (C-30)

Fine aggregate	weight (kg)	Density(Kg/m3)		crushing load(KN)	compressive strength(Mpa)	
		Individual	Average		Individual	Average
100% N.S	8.515	2522.963	2502.321	768.000	34.133	31.511
	8.321	2465.481		665.780	29.590	
	8.500	2518.519		693.210	30.809	
75% N.S & 25% M.S	8.375	2481.481	2433.580	712.220	31.654	32.923
	8.060	2388.148		702.800	31.236	
	8.205	2431.111		807.300	35.880	
50% N.S & 50% M.S	8.020	2376.296	2429.136	879.600	39.093	36.340
	8.160	2417.778		793.000	35.244	
	8.415	2493.333		780.320	34.681	
25% N.S & 75% M.S	8.140	2411.852	2439.012	745.000	33.111	33.108
	8.305	2460.741		746.600	33.182	
	8.250	2444.444		743.200	33.031	
100% M.S	8.650	2562.963	2474.074	724.900	32.218	33.653
	8.175	2422.222		770.000	34.222	
	8.225	2437.037		776.700	34.520	

4.4.2 Tensile strength

The cylindrical specimens were taken out of the curing tank at the age of 28th day and tested to measure the tensile strength capacity of the concrete by using splitting test. The tensile strength test results are given in the table below.

Table 4.22: 28th day tensile strength (C-25)

Fine aggregate	weight (kg)	Density(Kg/m3)		crushing load(KN)	Tensile strength(Mpa)	
		Individual	Average		individual	Average
100% N.S	3.880	2470.079		69.80	2.221	
	3.780	2406.417		96.000	3.054	
	3.800	2419.149	2431.882	72.000	2.291	2.520
75% N.S & 25% M.S	3.780	2406.417		85.300	2.715	
	3.750	2387.319		84.700	2.696	
	3.770	2400.051	2397.929	83.000	2.641	2.680
50% N.S & 50% M.S	3.830	2438.248		102.800	3.272	
	3.600	2291.826		90.200	2.871	
	3.650	2323.657	2351.244	95.300	3.033	3.060
25% N.S & 75% M.S	3.800	2419.149		90.300	2.874	
	3.800	2419.149		81.100	2.581	
	3.780	2406.417	2414.905	80.000	2.546	2.660
100% M.S	3.760	2393.685		79.200	2.521	
	3.750	2387.319		95.000	3.023	
	3.760	2393.685	2391.563	93.100	2.963	2.840

Chapter 5 DISCUSSION OF TEST RESULTS

5.1 General

The main objective of the laboratory test work was to assess suitability of fine aggregate materials used in Jimma area for the production of concrete and to determine whether replacing the natural sand with manufactured sand in different proportion improves the workability compressive strength and tensile strength of the concrete produced by it.

In this section the test results are presented and analyzed with respect to the requirements of concrete compressive strength, tensile strength and workability.

5.2 Discussion of results

5.2.1Physical properties of fine aggregate (NS and MS)

1 Shape and surface texture

The natural sand is round in shape and smooth in surface texture which is good in terms of gradation but gives poor interlocking and bonding capabilities . However the manufactured sand is irregular in shape and rough in texture which is good in terms of compactness and bond strength.

2 Silt content

The silt content of the natural sand and manufactured sands is 0.433% and 2.330% respectively which satisfy the requirements of ASTM which is less than 5%.

3 Dry unit weight

The unit weight of the natural sand and manufactured sand is 1662.26kg/m^3 and 1755.56kg/m^3 respectively. The natural sand satisfies the requirements of ASTM which states to be in the range 1450kg/m^3 to 1750kg/m^3 but the manufactured sand is above the requirement. This means that the volume that the manufactured sand occupies in the concrete is above the required value.

4 Absorption capacity

ASTM standards states the water absorption of fine aggregate should be in the range of 0.2 to 4%. Absorption capacity of the natural sand and manufactured sand is 0.166% and 2.04% respectively the natural sand is below the specified range but the manufactured sand satisfies the requirement. Low absorption results segregation and bleeding

5 Specific gravity

ASTM standard states that the apparent specific gravity of a normal concrete aggregate should be between the range of 2.3 and 2.9. Apparent specific gravity of the natural sand and manufactured sand is 2.656 and 2.542 respectively which satisfies the requirement.

6 Fineness modulus

Fineness modulus of the natural sand is 2.69 which satisfy the requirements of ASTM for the fineness modulus to not be less than 2.0 and more than 3, but the manufactured sand had fineness modulus of 3.35 which is above the given range. This also affects the workability of the concrete

Table 5.1 summery of the physical properties (N.S and M.S)

Property	N.S	M.S	ASTM	Remark
Shape and texture	Round, smooth	irregular, rough	-	M.S has higher cohesion and strength
Silt content	0.43	2.3	< 5	Both sand type satisfies the standard
Dry unit weight	1662.26 kg/m3	1755.56kg/m3	1450kg/m3-1750kg/m3	The M.S is above the limit
Absorption capacity	0.166	2.04	0.2-4	The N.S has low absorption
Fineness modulus	2.69	3.35	2-3	The M.S is above the range

7 Gradation

According to the ASTM gradation limits the natural sand is in between the limits but the manufactured sand is below the lower limit at the sieve sizes of 1.18mm and 2.36. Gradation of aggregates is one of the most important quality parameters that predominantly influence the properties of a concrete but the manufactured sand is failed to satisfy this requirement. The figures shown below illustrate the gradation of both natural sand, manufactured sand and 50% blending of both.

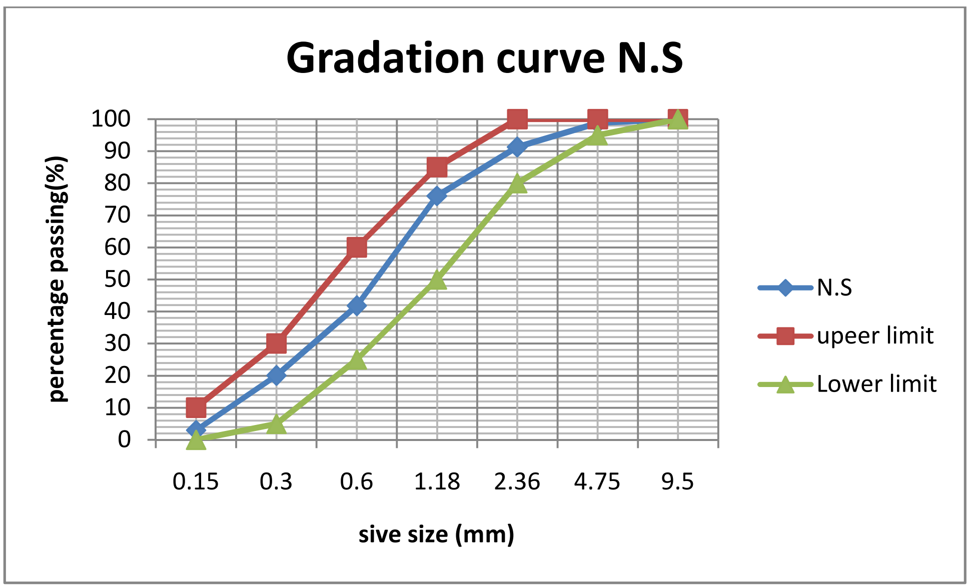

Figure 5.1: Gradation curve (N.S)

From the figure above we can clearly see that the natural sand is well in the range given by the ASTM standards.

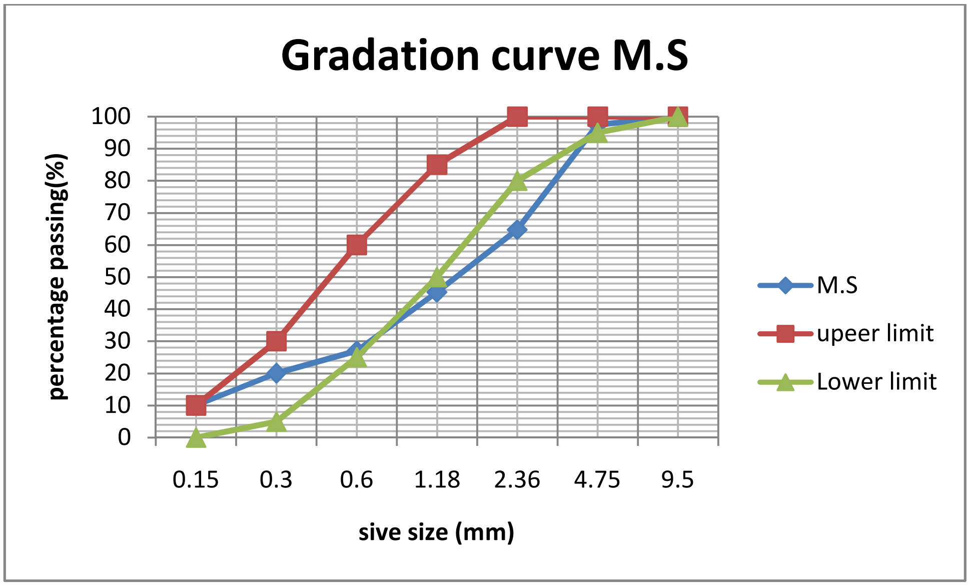

Figure 5.2: Gradation curve (M.S)

From the figure above we can see that the manufactured sand has a gradation problem.

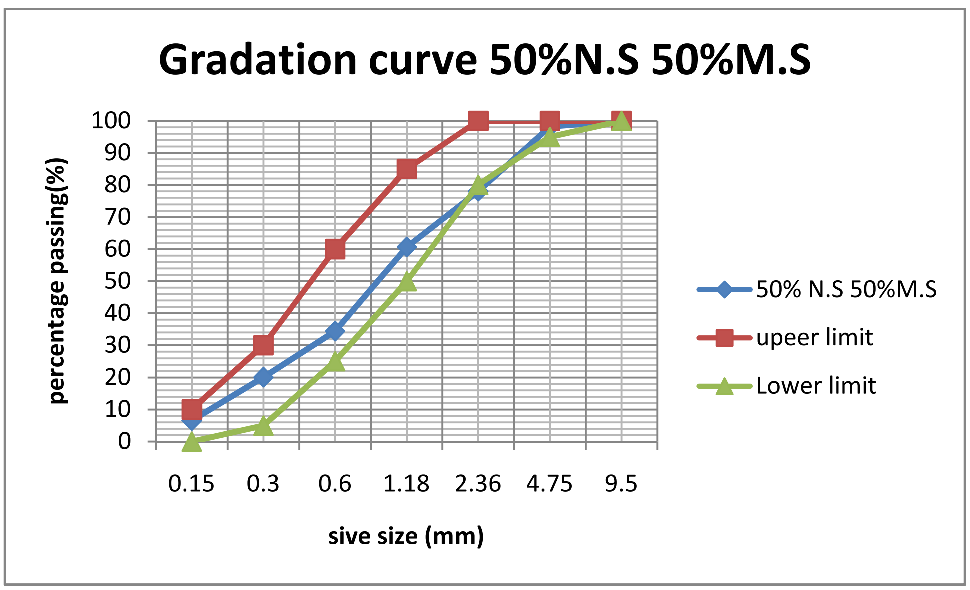

Figure 5.3: Gradation curve 50% N.S & 50% M.S

When the natural sand is replaced 50% by the manufactured sand as expected the gradation is lowered. From the point of view of the manufactured addition of natural sand improves the gradation.

5.2.2 Fresh concrete properties

Workability describes the case with which freshly mixed concrete can be laid, transported and to a large extent it is controlled by the amount of water in concrete.

The results of the slump tests carried out on the fresh concrete gave an indication of the workability of the concrete. After the trial mix was done for the concrete mix with fully natural sand as fine aggregate the slump result measured was 20mm which shows low workability.

From the trial mix the final mix design is decided and the workability showed improvements in most of the sand proportions. The results are shown in the table below.

Table 5.2: Observed slumps of the final mix

No.	Sand proportions	Water cement ratio	Measured slump(mm)
1	100% Natural Sand	0.54	25
2	75% Natural Sand & 25% Manufactured sand	0.54	27
3	50% Natural Sand & 50% Manufactured sand	0.54	35
4	25% Natural Sand & 75% Manufactured sand	0.54	30
5	100% Manufactured sand	0.54	40
6	100% Natural Sand	0.47	30
7	75% Natural Sand & 25% Manufactured sand	0.47	39
8	50% Natural Sand & 50% Manufactured sand	0.47	55
9	25% Natural Sand & 75% Manufactured sand	0.47	33
10	100% Manufactured sand	0.47	60

The result shows that the workability increases with the increases in percentage of manufactured sand.

5.2.3 Hardened concrete properties

1 Compressive strength

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

The compressive strength of the concrete specimens was determined by testing concrete cubes of size 150mm. All specimens were weighed and measured to determine the area of the cube and density of the concrete. The hardened properties of the concrete have been determined at the ages of 7 and 28 days. At each age a minimum of three specimens were tested to ensure the accuracy of test results. The results are shown in the table below. The results are more illustrated in the following graphs

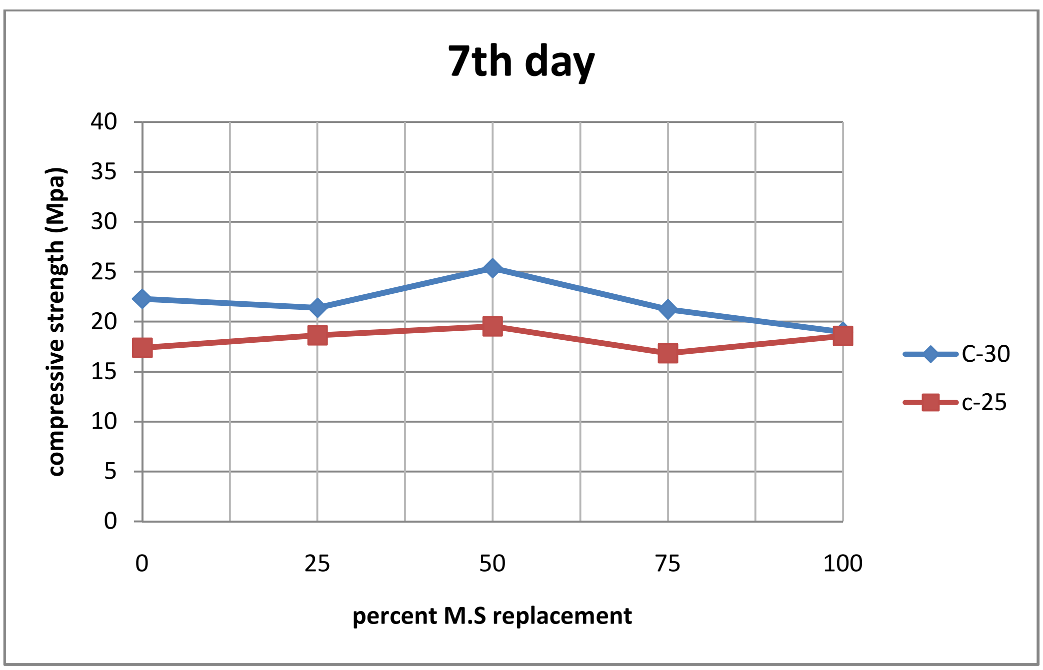

Figure 5.4: 7th day average compressive strength vs. M.S replacement(C-25 and C-30)

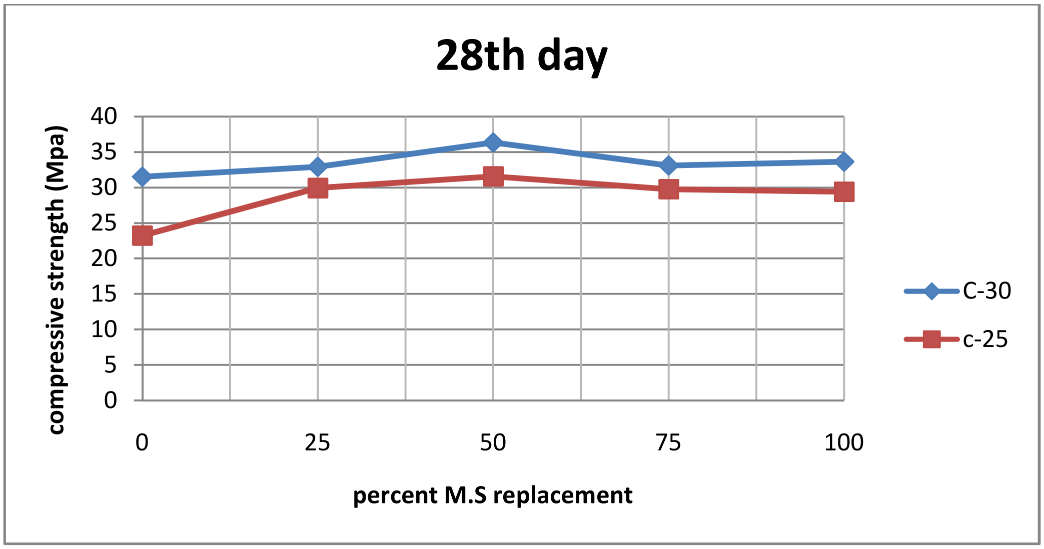

Figure 5.5: 28th day average compressive strength vs. M.S replacement (C-25 and C-30)

2 Tensile strength

The tensile strength was determined from splitting test which was performed on cylindrical specimens of dia. of 100mm and length 200mm. The test was done at the age of 28th day.

The graph shown below illustrates the average tensile strength for different manufactured sand proportions

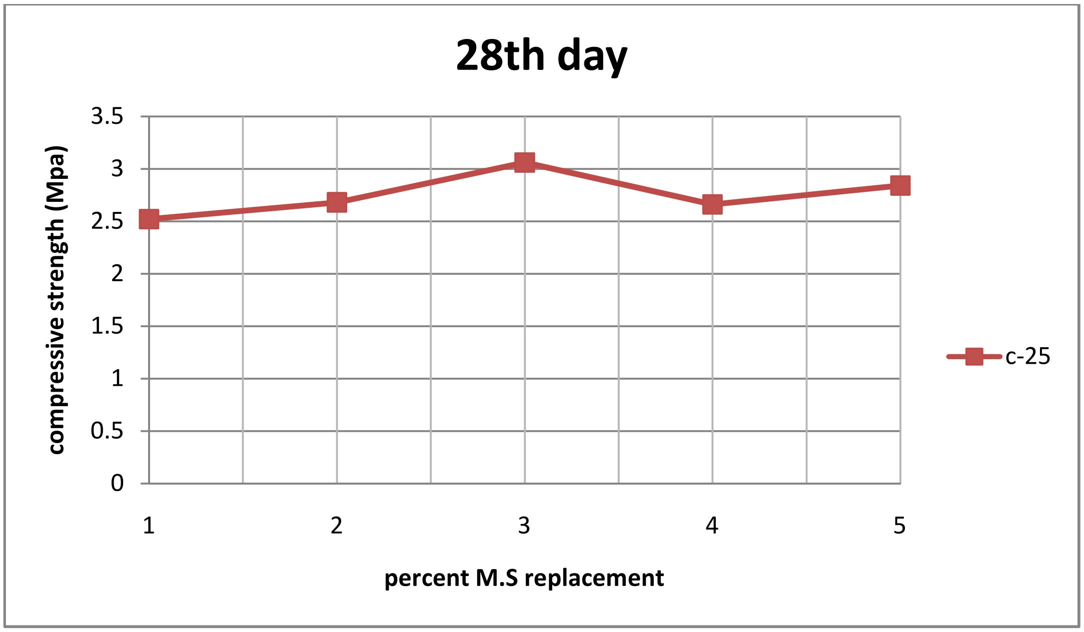

Figure 5.6: 28th day tensile strength vs. M.S replacement(C-25)

Generally, from the results it can be seen that the addition of manufactured sand resulted in increased compressive strength and tensile strength up to the 50% mark, after that it showed slight decrement on both.

The test results showed that for both, C-25 And C-30 concrete grades, the manufactured sand with 50%MS+ 50% NS was capable of achieving a higher compressive strength than using with other proportions of manufactured and natural sand.

The mix proportion with 100% natural sand showed compressive strength below the requirements for C-25 grade concrete.

It can be concluded that the optimum blending percentage with respect to compressive and tensile strength is 50% MS+ 50% NS for both C-25 and C-30 graded concrete. However, special cares have to be taken on the natural sand quality to achieve the desired concrete strength.

Chapter 6 CONCLUSIONS AND RECOMMENDATIONS

6.1 conclusion

1. The physical requirements of fine aggregates for good quality concrete which are Silt content, specific gravity, absorption and moisture content, the manufactured sand found to be within the specified limit but the unit weight was higher than the standard range and due to excessive fines the fineness modules was above the maximum value and the gradation was below the lower limit at some of the sieve sizes, therefore the manufactured sand should be improved in the production process.
2. The natural sand in Jimma area was found to be within the specified limits for most of the physical requirements, but the absorption capacity was found to be below the specified value.
3. When blending manufactured sand with natural sand at 50% ratio, the result showed better gradation which improves the manufactured sand gradation problem.
4. The slump test result shows that the workability of the fresh concrete increases as the percentage of manufactured sand increases. Therefore addition of manufactured sand can improves the workability of concrete.
5. The test results showed that for both, C-25 And C-30 concrete grades, with 50% MS+ 50% NS was capable of achieving a higher compressive strength than using with other proportions of manufactured and natural sand at all test ages.
6. The mix proportion with 100% natural sand (Gambela river sand) showed compressive strength below the requirements for C-25 grade concrete.
7. The Splitting tensile strength test shows that the tensile strength is maximum at 50% replacement of manufactured sand.
8. It can be concluded that the optimum blending percentage with respect to compressive and tensile strength is 50% MS+ 50% NS for both C-25 and C-30 graded concrete. However, special cares have to be taken on the natural sand quality to achieve the desired concrete strength.

6.2 Recommendations

1. The manufactured sand is not produced purposefully for use in concrete instead it is a by-product of the coarse aggregate crushing process this caused the grading problem and increased the amounts of the fines. Thus the manufactured sand should be produced purposefully to be used as concrete material.
2. The manufacturing process of manufactured sand should be given attention so as to provide well graded fine aggregate with fewer amounts of micro fines and Grading should obviously become part of a quality control measure with results of interest to the individual suppliers and their customers.
3. The natural sand (Gambela river sand) in Jimma area shown low compressive strength at all test ages which needs replacement by another sand type or blending with the manufactured sand.
4. The performance of buildings found in Jimma area which are constructed with concrete made with this natural sand (Gambela river sand) should be evaluated.
5. Further investigation should be done to asses other alternatives of fine aggregate with optimal cost.

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