Jimma University

School of Graduate Studies

Jimma Institute of Technology

Faculty of Civil and Environmental Engineering

Department of Civil Engineering

Construction Engineering and Management Stream

COMPARATIVE STUDY ON THE ENGINEERING PROPERTIES OF CRUSHED COARSE AGGREGATES USED IN JIMMA TOWN.

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 Civil Engineering (Construction Engineering and Management)

By: Temesgen Assefa

October 2017

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By: Temesgen Assefa

Advisor: Engr. Emer T. Quezon. (Professor-Full)

Co-Advisor: Engr. Kemal Ture. (M.Sc.)

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JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

CONSTRUCTION ENGINEERING AND MANAGEMENT STREAM

"Comparative Study On The Engineering Properties Of Crushed Coarse Aggregates Used In Jimma Town."

By Temesgen Assefa

APPROVED BY BOARD OF EXAMINERS:

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Declaration

I, the undersigned, declare that this thesis entitled: ***“Comparative Study On The Engineering Properties Of Crushed Coarse Aggregates Used In Jimma Town.”*** is my original work, and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material used for these have been dully acknowledged.

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

16-10-2017

Prof. Emer T. Quezon (Professor-Full) _______________ ______________

Advisor Signature Date

Engr. Kemal Ture, MSc

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Co-Advisor Signature Date

ACKNOWLEDGEMENT

First of all, I would like to gratefully acknowledge the Almighty God to get the chance of this program. My most profound gratitude goes to my advisor Emer T. Quezon (professor) and my Co-Advisor Engr. Kemal Ture (Msc) for all their limitless efforts in guiding me through my work and for providing me useful reference materials.

I would profoundly like to thank Engr. Fitsum Alemayehu for his technical pieces of advice, supervision and also for providing me with space and all other facilities to conduct part of my thesis carried out in Jimma Institute of Technology Laboratory. I would also like to extend my gratitude to Mr. Solomon for giving advice and showing all the possible ways of the aggregate quarry site to which I get to collect for the study of my research.

I would also like to use this opportunity to convey my gratitude to the academic staff of Department of Civil Engineering (Construction Engineering and Management Stream), Jimma Institute of Technology School of Civil and Environmental Engineering, and to my friends. Without their support and encouragement, I couldn't have this opportunity to complete my study. I also gratefully acknowledge the contributions of all those individuals who had contributed in one way or the other in the realization of this paper.

Finally, I would like to thank my parents and other members of my family for their unconditional support, encouragement, and love.

ABSTRACT

This experimental study carried out to investigate the quality and suitability of using locally available coarse aggregates in Jimma Town to make a concrete mix. Aggregate samples were collected from five different quarries according to ASTM sampling procedure. The experiments were performed on collected samples of coarse aggregates to evaluate their physical and mechanical properties as per ASTM and BS standards. Concrete compositions made, using the same aggregates were tested for mechanical properties (Engineering property and compressive strength). Concrete mixtures were prepared, tested and compared regarding Compressive strength and Engineering property. These tests were carried out to evaluate the strength properties at 7th day, 14th day and 28th day. The results of this study showed that the concrete made using Geruke quarry crushed coarse aggregate performed satisfactorily regarding mechanical properties. Moreover, their performance was found to be quite similar to those aggregates commonly available and used in the town of Jimma quarry sites such as Beda Buna, Sheteradion, Kisho, and Buna Board quarry crushed coarse aggregates. The result showed that sheteradion, kisho, and geruke crushed coarse aggregate, were within the acceptable limit of ASTM C-33 standards. Whereas beda buna and buna board crushed coarse aggregates showed insignificant amount (89.1% and 87.49% percent pass through sieve no 25.0mm) or below the standards. The other aggregate quality test for Bulk density, Surface water contents, Specific Gravity, Absorption, Aggregate Impact Value, Aggregate Crushing Value, Abrasion and Impact in the Los Angeles and soundness by Sodium, were noted within the stipulated standard and limits. Properties of the concrete, mostly depend on the characteristics of the aggregates. It was observed that except SCCA and KCCA aggregates, the rest of the aggregates revealed higher compressive strength which is satisfactorily. Therefore, it can be concluded that the strength and durability of concrete are greatly influenced by the quality, strength, and durability of the coarse aggregate used. The result substantiated that variation in the compressive strength of concrete mixes with BBCCA, SCCA, KCCA, BB'CCA, and GCCA, with the values of 33.8 Mpa, 29.6 Mpa, 28.3 Mpa,32.7 Mpa and 34.7 Mpa respectively.

Keywords: Compressive Strength, Concrete, Crushed Aggregate , Quarry

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ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
ACV	Aggregate Crushing Value
AIV	Aggregate Impact Value
ASTM	American Society for Testing and Materials
BS	British Standard
BBCCA	Beda Buna Crushed Coarse Aggregate
BB’CCA	Buna Board Crushed Coarse Aggregate
ES	Ethiopian Standard
GCCA	Geruke Crushed Coarse Aggregate
f_{ck} ,cube	mean concrete cube compressive strength
f_{cu}	specified characteristic cube compressive strength
FM	Fineness Modulus
KN	Kilo Newton
KCCA	Kisho Crushed Coarse Aggregate
LA	Los Angeles Abrasion
MSS	Magnesium Sulfate Solution
N.M.C	Natural Moisture Content
OPC	Ordinary Portland Cement
PSD	Particle Size Distribution
S	the coefficient for cement type used with the age function
SSD	Saturated Surface-Dry
SCCA	Sheteradion Crushed Coarse Aggregate
SSS	Sodium Sulfate Solution
W_{OD}	Weight of Oven Dray
$\beta cc(t)$	Age function for strength

CHAPTER ONE

INTRODUCTION

1.1 Background

Concrete is a composite material produced by the homogenous mixing of selected proportions of water, cement, and aggregates (fine and coarse).Strength is the most desired quality of a good concrete. It should be strong enough, at hardened state, to resist the various stresses to which it would be subjected. The compressive strength of concrete, therefore, is the value of test strength below which is not more than a prescribed percentage of the test results should [1].

To predict the behavior of concrete under general loading requires an understanding of the effects of aggregate properties and characteristics. This knowledge can only be gained through extensive testing and observation. It is well recognized that coarse aggregate plays an essential role in concrete. Coarse aggregate typically occupies over one-third of the volume of concrete, and research indicates that changes in coarse aggregate can change the strength and fracture properties of concrete.

Aggregates, which are one of the materials used in making concrete, are chemically inert solid particles of selected sizes, held together by the hardened cement paste, which acts as the binder to aggregates. In a normal concrete, 75 to 85% of the volume of concrete is aggregate that makes the cost of concrete relatively low. The choice of aggregate is determined by the proposed use and importance of structure, environmental conditions to which the structure will be exposed and the availability of aggregate within an economic distance [3]. Crushed aggregate tend to improve the strength because of the interlocking of the angular particles but reduce flow, while rounded aggregate improves the flow because of lower internal friction [5].

The shape and surface texture of aggregate particles influence the properties of fresh concrete more than hardened concrete. Compared to smooth and rounded particles, rough-textured, angular, and elongated particles require more cement paste to produce workable concrete mixtures, thus increasing the cost [6]. Aggregates in concrete serve three main functions: they provide a relatively cheap filler by rigid interlocking with cementitious binders; they serve to provide a cohesive mass of solids that resists the action of applied loads, percolation of moisture, the action of weather, and abrasion and erosion and, they reduce the volume changes resulting from the setting and hardening process from moisture changes in the cementitious paste thus reducing the cracking possibility of concrete [3]. The surface texture of some materials and structures is of importance to civil engineers. For example, smooth texture of aggregate particles is needed in Portland cement concrete to improve workability during mixing and placing. In contrast, rough texture of aggregate particles is needed in asphalt concrete mixtures to provide a stable pavement layer that resists deformation under the action of load [7].

Coarse aggregate is usually greater than 4.75 mm (retained on a No. 4 sieve), while fine aggregate is less than 4.75 mm (passing the No. 4 sieve). The compressive aggregate strength is an important factor in the selection of aggregate. When determining the strength of normal concrete, most concrete aggregates are several times stronger than the other components in concrete and therefore not a factor in the strength of normal strength concrete. For this reason, the quality of the coarse aggregates is essential when considering the quality of the concrete itself. The properties of coarse aggregates do grossly affect the durability and structural performance of concrete. Such properties as size, shape, and surface conditions of aggregates are considered alongside the mineral composition of the rock material from which the aggregate formed a part [1].

Natural sources for aggregates include rock quarries, river run deposits, and. Gravel pits .crushed stones are the result of processing rocks from quarries having a rough texture.In Portland cement concrete, 60% to 75% of the volume and 79% to 85% of the weight is made up of aggregates. Therefore, maximizing the amount of aggregate, to a certain extent, improves the quality and economy of the mix [7].

The role of coarse aggregate in concrete is central to this report. While the topic has been under study by a different researcher, an understanding of the effects of coarse aggregate has become increasingly more important with the introduction of high strength concretes, since coarse aggregate plays increasingly more important character in concrete behavior as strength increases. In normal-strength concrete, this research looks the variables considered are coarse aggregate engineering characteristics and properties to achieve crushed coarse aggregate from locally available materials according to the requirement of fresh (workability measurements) and harden properties in normal concretes.

1.2 Statement of the Problem

Strength performance remains the most important property of structural concrete, from an engineering viewpoint. The relation between concrete composition and mechanical properties has long been a matter of research interest. The strength of the concrete is determined by the characteristics of the cement, coarse aggregate, mixture proportions including w/c and the interface. For the same quality cement, different types of coarse aggregate with different shape, texture, mineralogy and strength may result in different concrete strengths. However, the limitation of the water/cement ratio (W/C) concept is becoming more apparent with the development of high-performance concrete, in which the aggregate plays a more important role.

Density of concrete is determined by the aggregate density as well as soft with porous concrete produce weak concrete with lower wear resistance. That’s why the overall or mechanical properties of concrete depends on the certain properties of aggregates like source of aggregates, normal or light or heavy weight aggregate, size of aggregate, shape of aggregate, crushing type of aggregates, angularity index, surface texture, modulus of elasticity, bulk density, specific gravity, absorption and moisture content, bulking of aggregates, cleanliness, soundness of aggregates, thermal properties and grading of aggregates. Moreover, Interfacial Transition Zone (contact surface between aggregate and cement paste) plays an important role in strength and durability of concrete. But aggregates should be clean and free from impurities which are likely to interfere with the process of hydration, prevention of effective bond between the aggregates and matrix and it reduces the durability of concrete. Sometimes excessive silt and clay contained in the fine or coarse aggregate may result in increased shrinkage or increased permeability in addition to poor bond characteristics [1].

Adherence reducing material like silt and clay must not be covered by aggregates surface and both aggregates and surface geometry must not allow any spaces which are being arisen from strike of cement particles [2]. This situation is defined as ‘wall effects’. To avoid such kind of spaces aggregates shape is a key fact and if aggregates voids are minimised, the amount of cement paste required to fill those voids also minimised maintaining workability and strength.

It is difficult to really measure the shape of irregular body like concrete aggregate which are derived from rocks. Not only have the characteristics of the parent rock but also the type of crusher used in crushing, influence the shape of aggregates. Research shows that, there is a relationship between the voids of aggregates and shape, texture and grading of aggregates [3]. In rounded, cubical and well graded particles exhibits lower void content than flaky, elongated and angular aggregates.

Roundness and angularity are the important characteristics of aggregates. Roundness is the outline of the particle and it may be measured in terms of convexity where angularity indicates the sharpness of the edges and corners [4, 5]. However, flaky and elongated particles can produce harsh mixtures and seriously effect in workability. An excess of poorly shaped particles could reduce the strength of concrete through the increase of water demand. In addition, flat particles can be oriented in such a way that they could impair the strength and the durability of concrete [6, 7]. In concrete pavements, flat particles near the surface inhibit bleed water from entering mortar above particle, thus contributing to the deterioration of the surface [8]. So from literature it is clear that crushing type of aggregates definitely has effects on properties of concrete because crushing type of aggregate can change and control the shape factor directly. To identify the effects on mechanical properties of concrete (slump value and compressive strength) of Impact Crushed and Vertically Shafted aggregates this study will be conveyed.

In Ethiopia the use of proper coarse aggregate for the production of concrete is not as much as it is expected, because most contractors are looking only the benefit that they can get out of the construction project, so this poor quality coarse aggregate have its numerous implications resulting in building poor quality products. [8].

The quality of coarse aggregate in Jimma is also one basic issue / problem that is not properly used and at the end of the day the poor quality of the aggregate have its big impact on the creation of poor quality of building projects like impact at its fresh and hardened state or weak quality issue was an issue in the different quarry sites in Jimma Town so the researcher was comparing the different crushed coarse aggregate in Jimma Town.

1.3 Research Question

This research was conducted to answer the following questions.

- ✓ What are the different Engineering properties of crushed coarse aggregates implication on the quality of the material.
- ✓ What are the influence of crushed coarse aggregates on hardened concrete.
- ✓ Does the result of the test within the limit of the international standard and local specifications?

1.4 Objectives

1.4.1 General objective

The main objective of the research was to study the engineering properties of crushed coarse aggregates and its influence on the strength of concrete used in Jimma Town .

1.4.2 Specific Objectives

To meet the above expectations, the proposed study have specific objectives listed below

- ✓ To identify the engineering properties of crushed Coarse Aggregates used in Jimma Town.
- ✓ To determine the effect of crushed Coarse aggregates on Hardened Concrete.
- ✓ To compare test results with standard specifications.

1.5 Significance of study

This study was concerned with the assessment on the sources and effects of coarse aggregate on compressive strength of concrete in different quarry sites of Jimma Town.

Therefore, the study was significant for the following reasons:

- ✓ The results to be obtained from this research was helpful for other researches that the study solve the quality problems of the aggregates on the concreting works.
- ✓ The study was used as some paramount importance to the government and authorities at the future to have a chance to put their ideas.
- ✓ The study or the outcome of the research was used as a mechanism or tool to prevent bad construction practices regarding quality wise.
- ✓ The study was used as a bench mark information to those scholars who want to conduct future detailed studies on coarse aggregate and other related issues.

1.6 Scope of the Study

This particular research was focused on the analysis, the issues of investigating the different coarse aggregate effects on compressive strength of concrete in Jimma Town and to analyze with standards and specifications.

CHAPTER TWO

LITERATURE REVIEW

Aggregates play an important role in civil engineering construction. The major constituents of ordinary concretes are crushed rocks or gravels used as coarse aggregates and sands used as fine aggregates) [1]. Concrete has been the most common building material for many years. Much of the developed world has infrastructures built with various forms of concrete. Mass concrete dams, reinforced concrete buildings, prestressed concrete bridges, and precast concrete components are some typical examples. It is anticipated that the rest of the developing world will use these forms of construction in their future development of infrastructures [5]..

Traditionally, concrete is a composite consisting of the dispersed phase of aggregates (ranging from its maximum size coarse aggregates down to the fine sand particles) embedded in the matrix of cement paste [3].. This is a Portland cement concrete is a composite material made by combining cement, supplementary cementing materials, aggregates, water, and chemical admixtures in suitable proportions and allowing the resulting mixture to set and harden over time [2].. Next below briefly discussed the major and common ingredients of Portland cement concrete.

Aggregate is a broad encompassing boulder, cobbles, crushed stone, gravel, air-cooled blast furnace slag, native and manufactured sands, and manufactured and natural lightweight aggregates. They are usually distinguished by size as follows: Boulders Larger than 6 in, Cobbles 6 to 3 in, Coarse aggregate 3 into No. 4 sieve, Fine aggregate No. 4 sieve to No. 200 sieve, Mineral filler Material passing No. 200 sieve.

In most concrete construction, normal-weight aggregates are obtained by draining riverbeds or mining and crunching formational material.

In general, aggregates in concrete have been grouped according to their sizes into fine and coarse aggregates. Although a full range of physical properties may be obtained, those of major interest to a civil engineer include specific gravity (or density), porosity and particle size distribution (or grading). Properties such as shape and surface texture of aggregates are usually stated in descriptive terms [6].

In Portland-cement concrete aggregates comprise the greatest volume percentage, mortar, or asphaltic concrete. In a Portland-cement concrete mix, the coarse and fine aggregates occupy about 60 to 75% of the total mix volume [12] . Aggregates make up about 75% of the volume of concrete, so their properties have a large influence on the properties of the concrete in [1]. 85% Aggregates form the body of the concrete, reduce the shrinkage and effect economy and have considerable influence on the properties of the concrete. It is therefore significantly important to obtain right type and quality of aggregates at a site. They should be clean, hard, strong, and durable and graded in size to achieve utmost economy from the [8].

The acceptability of a coarse or fine aggregate for use in concrete or mortar is judged by many properties including gradation, amount of fine material passing the No. 200 sieve, hardness, particle shape, volume stability, potential alkali reactivity. For aggregates used in general building construction, property limits are provided in ASTM C33, ‘‘Specification for Concrete Aggregates [7].

2.1 Physical and Geometrical properties of coarse aggregate Grading

ASTM C33 and C136, ES C.D3.201 and BS 812-103.1 provide ranges of fine- and coarse-aggregate grading limits. The particle size distribution of an aggregate (often expressed as a percentage by mass of the total mass of aggregate) is called its grading. The separation into various sizes is based on a standard series of sieves of prescribed openings [4]. The grading of natural fine aggregates or sand depends on the source. The maximum size of particles BS is limited to those passing the 5 mm (4.75 mm in ASTM and ES) sieve. Other than river gravels, coarse aggregates are produced in quarries by crushing of rocks. BS Standard usually provide overall limits on the grading of aggregates [9].

Fineness modulus (FM) is the sum of the cumulative percentages retained on sieves (each was the only sieve) starting from the size of 150 mm to the maximum size and divided by 100. It is often applied to fine aggregate as an indication of its [1].It is to be noted that a fine grading has a lower value of fineness modulus. The same value of fineness modulus may be produced by two or more different grading [11]. ASTM, BS, and ES provide the range of FM for fine aggregates ASTM C33 2.15-3.38, BS 882 1.15-4.01 and ES C.D3.201 2.4-2.9.

There are differences between the limits for ES, ASTM and BS standards. In general, BS permits a wider range for grading of both fine and coarse aggregates. A grading in which one or more intermediate size fractions are missing is termed “gap graded.” This is in contrast to the continuous grading commonly used [7].

Table 1: Fine aggregate gradation standard table of ES, ASTM, and BS

sieve Size mm		ES limits (%)		ASTM limits (%)		BS limits (%)	
ES and ASTM sieve size	BS sieve size	Min.	Max.	Min.	Max.	Min.	Max.
9.5	10	100	100	100	100	100	100
4.75	5	95	100	95	100	89	100
2.36	2.36	80	100	80	100	60	100
1.18	1.18	50	85	50	85	30	100
0.6	0.6	25	60	25	60	15	100
0.3	0.3	10	30	10	30	5	70
0.15	0.15	2	10	2	10	0	15

Table 2: Coarse aggregate gradation standard table of ES, ASTM, and BS

sieve Size mm(in)			ES limits (%)		ASTM limits (%)		BS limits (%)	
ES sieve size	ASTM	BS sieve size	Min.	Max.	Min.	Max.	Min.	Max.
37.5	37.5	37.5	100	100	100	100	100	100
19	25	20	95	100	90	100	90	100
13.2	19	14	-	-	40	85	40	80
9.5	12.5	10	25	55	10	40	30	60
4.75	9.5	5	0	10	0	15	0	10
-	4.75	-	-	-	0	5	-	-

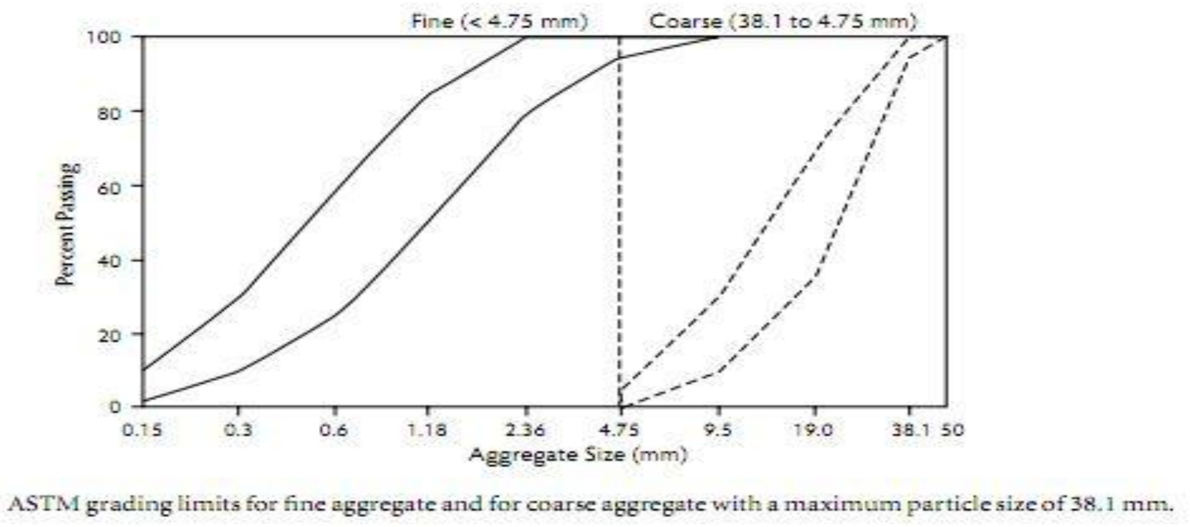

Figure 1: ASTM Grading Limit, Source: Concrete Construction Engineering Handbook 2nd edition

2.2 Specific gravity and water absorption

The specific gravity of an aggregate is the mass of the aggregate in air divided by the mass of an equal volume of water. Test methods for finding specific gravity of aggregates are described in ASTM C 127, "Specific Gravity and Absorption of Coarse Aggregate," and ASTM C 128, "Specific Gravity and Absorption of Fine Aggregate[3]. Coarse and fine aggregate will have absorption levels (moisture contents at SSD) in the range of 0.2% to 4% and 0.2% to 2%, respectively [6]. According to aggregates for concrete bulletin book the absorption of normal concrete, aggregates is 0.5- 4 [7].

The specific gravity and porosity of aggregates significantly influence the strength and absorption of concrete. The specific gravity of aggregates is telling of its quality. A low specific gravity indicates high porosity and therefore poor durability and low strength. The concrete density will greatly depend on specific gravity [6]. Each piece of aggregate may have a few internal pores. These pores may be filled with water (saturated condition), partially or completely dry (oven-dry). Hence, the bulk unit weight of aggregates may be expressed in the completely dry state (bulk specific gravity) or the saturated state (bulk specific gravity, saturated-surface-dry basis). Specific test methods (ASTM C 127) are used to determine such values. They form the two extreme states of moisture in a particle of aggregate. In practice, the actual amount of moisture for aggregates stored under protection from the weather may be in between these two extremes. When the pores of each piece of aggregate are filled with water, but without any water adhering on their surfaces, it is in its "saturated-surface-dry" (SSD) condition. These typically have specific gravities between 2.0 and 3.0 [7]. ACI educational bulletin book specified the range of normal concrete aggregates specific gravity is in between of 2.3-2.9 [7].

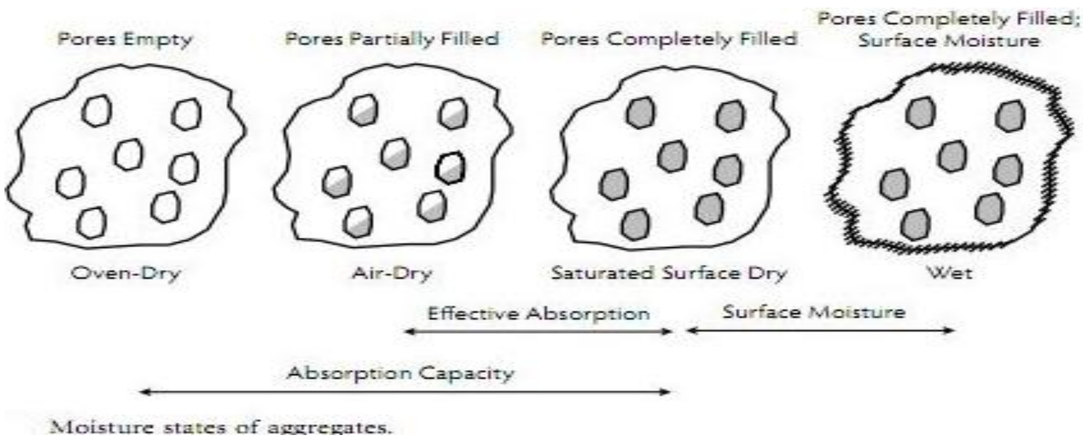

Figure 2: Moisture States of Aggregate Source: Concrete Construction Engineering Handbook 2nd Edition

The amount of water absorbed into the voids per unit mass of oven-dry aggregates is called the “absorption.” When the aggregates are placed together in bulk, there are voids between the particles. The packing of aggregates depends on their sizes and the amount of each size as well as the shape of the particles [9].

2.3 Shape of aggregates

Particle shape is defined regarding "compactness," which is a measure of whether the particle is compact in shape, which is, if it is close to being spherical or cubical as opposed to being flat (disk-like) or elongated (needle-like) [7].ASTM and BS 882 limits flakiness index value for coarse aggregates is 35 and 40.

Natural sand and gravel have a round, smooth particle shape. Crushed aggregate (course and fine) may have shapes that are flat and elongated, angular, cubical, disk, or rod-like. These shapes result from the crushing equipment employed and the aggregate mineralogy. Extreme angularity and elongation increase the amount of cement required to give strength, difficulty in finishing, and effort required to pump the concrete. Flat and elongated particles also increase the amount of required mixing water. The bond between angular particles is greater than that between smooth particles. Adequately graded angular particles can take advantage of this property and offset the increase in water required to produce concrete with cement content and strength equal to that of a smooth-stone mix [7].

Figure 3: Shape of Aggregate
Source: Concrete Technology

The chief objection to flat or elongated particles of aggregate is the detrimental effect on workability and the resulting necessity for more highly sanded mixes and consequent use of more cement and water [5]. A moderate percentage (on the order of 25 percent of any size) of flat or elongated fragments in the coarse aggregate has no significant effect on the workability or cost of concrete [10].

2.4 Amount of Fine Material Passing the No. 200 Sieve

The material was passing the No. 200 sieve is clay, silt, or a combination of the two. It increases the water demand of the aggregate [2]. Large amounts of materials smaller than No. 200 may also indicate the presence of clay coatings on the coarse aggregate that would decrease bond of the aggregate to the cement matrix. A test method is given in ASTM C117 and C33 on BS 812-103.1, ''Materials Finer than 75µm Sieve in Mineral Aggregates by Washing. [16].

Permissible percentages, by weight, are commonly stipulated by specification on ASTM the maximum percentage of fine material passing 75µm is 5 % on ES; silt content 6% ASTM, on BS 4%. Fortunately, excesses of contaminating substances may frequently be removed by simple treatment. Silt, clay, powdery coatings, soluble chemical salts, and certain lightweight materials are usually removable by washing [8].

2.5 Soundness

Soundness is defined as the ability of aggregate to resist changes in volume as a result of changes in physical condition. Aggregate soundness is measured by ASTM C88, ''Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate.'' This test measures the amount of aggregate degradation when exposed to alternating cycles of wetting and drying in a sulfate solution. [7].Under ASTM C33 the maximum value for SSSV and MSSV is 12% and 18% respectively.

2.6 Unit Weight

The bulk density or unit weight of an aggregate is the mass or weight of the aggregate required to fill a container of a specified unit volume. The volume referred to here is that occupied by both aggregates and the voids between aggregate particles [9]. ACI also defined that the bulk density (previously "unit weight" or sometimes "dry-rodded unit weight") of an aggregate is the mass of the aggregate divided by the volume of particles and the voids between particles [13]. Aggregate bulk density depends on their packing, the particles shape and size, the grading and the moisture content. For coarse aggregate, a higher bulk density is an indication of fewer voids to be filled with sand and cement [5].

The approximate bulk density of aggregate commonly used in normal-weight concrete ranges from about 1200 to 1750 kg/m3 (75 to 110 lb/ft3) [7]. According to ACI bulletin educational book the unit weight of normal concrete is in between of 1280-1920kg/m^3 [20]. Methods for determining the bulk density of aggregates and void content are given in ASTM C 29, BS 812.ASTM C 29 provides for the determination of bulk density of aggregates with a maximum size of 125 mm (5 in.) and smaller.

The method most commonly used requires placing three layers of oven-dry aggregate in a container of known volume, rodding each layer 25 times with a tamping rod, leveling off the surface, and determining the mass of the container and its contents. The mass of the container is subtracted to give the mass of the aggregate, and the bulk density is the aggregate mass divided by the volume of the container. For aggregates having a maximum size greater than 37.5 mm (1-1/2 in.) and loose bulk density is desired, the container is simply filled to overflowing with a shovel before leveling it and determining its mass [5].

2.7 Concrete aggregates quality

The quality emphasis in the construction industry is on the ability to conform to established requirements. Requirements are the determined characteristics of a product, process or service as specified in the contractual agreement and a characteristic is any specification or property that defines the nature of those products, processes or services, which are determined initially by the client [6].

Aggregates must conform to certain standards for optimum engineering use: they must be clean, hard, strong, durable particles free of absorbed chemicals, coatings of clay, and other fine materials in amounts that could affect hydration and bond of the cement paste. Aggregates should be tested before they are used in concrete [7].The fine and coarse aggregates occupy 60% to 75% of the concrete volume (70% to 85% by mass) and strongly influence the concrete's freshly mixed and hardened properties, mixture proportions, and economy. Natural gravel and sand are usually dug or dredged from a pit, river, lake, or seabed. Crushed stone is produced by crushing quarry rock, boulders, cobbles, or large-size gravel. Crushed air-cooled blast-furnace slag is also used as fine or coarse aggregate. The aggregates are usually washed and graded at the pit or plant. Some variation in the type, quality, cleanliness, grading, moisture content, and other properties is expected [8].

2.8 Why evaluate construction project concrete aggregates quality?

The fine and coarse aggregates occupy 60% to 75% of the concrete volume (70% to 85% by mass) and strongly influence the concrete's freshly mixed and hardened properties, mixture proportions, and economy [9].Materials obtained from suppliers or work performed percentage should be within the acceptable quality level. Problems with materials or goods are corrected after delivery of the product [7].The choice in selecting aggregate, for economic reasons, is usually limited to local deposits. Good judgment in making this choice involves an appreciation of the desirable and undesirable characteristics that determine the aggregate quality and of the practicability of improving available materials by suitable processing [2].

Deterioration of concrete has been traced in many instances to the use of unsuitable aggregate. Suitable aggregate is composed essentially of clean, uncoated, properly shaped particles of strong, durable materials.

CHAPTER THREE

MATERIALS AND RESEARCH METHODOLOGY

3.1 Study area

Jimma zone is one of the thirteen zones of Oromia regional, state in which geographically lies in the southwestern part of Ethiopia. Jimma Town is the capital of the zone that is 345 km far away from Addis Ababa, the capital city of Ethiopia. It covers a total surface area of 19,305.5 km2. According to the 2007, Population and Housing Census of Ethiopia, the total population of the Jimma zone was 2,486,155. The zone bordered in Northwest by Illubabor, by East by Wellega and in West by Shewa zones as well as in the south by Southern Nations and Nationalities People's Regional State. In general, the elevation of the topographical feature varies from 1000 to 3360 m above sea level with average maximum and minimum temperatures in the range of 25–30°C.

The present study was conducted in five locations in Jimma Town : namely, Beda Buna quarry crushed aggregates, Sheteradion quarry crushed aggregates, Kisho quarry crushed aggregates , Buna Board quarry crushed aggregates and Geruke quarry crushed aggregate sites There is the reason to choose Jimma Town as the Study area; that this research was conceded to find out the quality level of the construction material, especially in the case of concrete making ingredients. In the town, the construction a project has appears fast and actively developing. This study, therefore, is carried out in Jimma Town and focuses on the use of crushed coarse aggregate which fulfills the quality conditions for the construction projects as concreting materials.

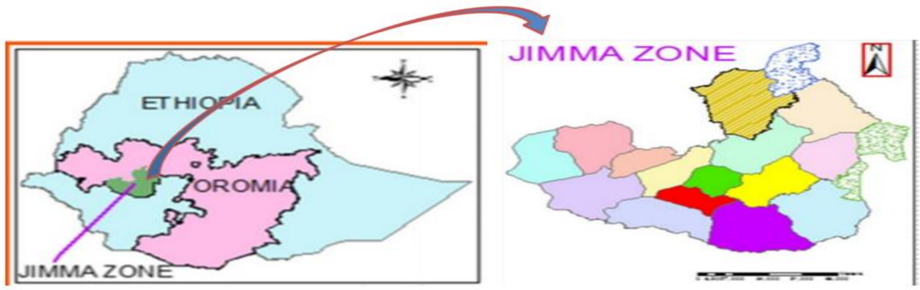

Figure 4: Map showing the locations of study quary sites

3.2 Materials

3.1.1 Water

The water content of concrete is influenced by some factors, such as aggregate size, aggregate shape, aggregate texture, workability, water-cement ratio, cement and other supplementary cementitious material type and content, chemical admixture and environmental conditions. In this study potable water was used.

3.1.2 Cement

Ordinary Portland cement type I- CEM I 42.5 N, conforming to the requirements of AASHTO M-85 Specification was used in the test.

Table 3: Properties of Ordinary Portland cement (OPC).

Type of test	Method of testing	Test Result		AASHTO M-85 Specification
Determination of setting time	AASHTO T-128-97 (BS EN 196-3) vicat test	initial setting time	80	Min. 45 minute
		final setting time	162	Max. 375 Minute
Determination of Consistency	AASHTO T-131-01(BS EN 196-4)	6.0		-
Determination of Fineness	AASHTO T-129-01-01(BS EN 196-6)	150 µm(No. 100)	99.2%	-
		75µm (No 200)	90.2%	-

3.1.3 Coarse Aggregate

The objective of this study was to determine the engineering properties and characteristics of crushed aggregate in Jimma Town. For this study five quarries crushed coarse aggregates were used; as follows; Table 4 below shows locations of aggregates that were tested for aggregate characterization tests.

Table 4: location and source of aggregate

No.	Location of quarry crushed Aggregate	Source
1	Beda buna quarry crushed aggregates	From ajip area
2	Ssheteradion quarry crushed aggregates	From yefa bula area
3	Kisho quarry crushed aggregates	From amist kelo area
4	Buna board quarry crushed aggregates	From amist kelo area
5	Geruke quarry crushed aggregates	From amist kelo area

Figure 5: BBCCA and SCCA quarry site and filed sample

Figure 6: KCCA and BB'CCA quarry site and filed sample

Figure 7: GCCA quarry site and filed sample

Crushed coarse aggregate with a maximum size of 20 mm, different specific gravity in the range of 2.805-2.855 and complying with ASTM C-33 was used.

Natural Sand

Sand with mainly a specific gravity of 2.595 was used as fine aggregate in this study.Sand was brought from Gambella which is one of the nine state of Ethiopia; located about 715 km away from the capital city of Ethiopia; Addis Ababa and 369 km from Jimma.

3.1.1 Study Design

To investigate the quality and availability of suitable concrete making aggregates in Jimma Town, test results of coarse aggregate and fine aggregate samples were collected at Jimma Institute of Technology Laboratory and Testing center. The collected data consists, test results of 3 quintal fine aggregate samples of Gambella sand from the market and four coarse aggregates with 2.5 quintals samples from 5 different Quarry Crushed Coarse aggregates sources. The research program was divided into two main Category classes as outlined below:

Category class one

In Category class one, the Aggregate collected from their source and tested to determine its physical, mechanical and chemical properties. The tests were carried out by the appropriate ASTM, AASHTO, ACI, ES and BS were applicable (Appendix A). With this understanding, the requirements of the properties of Crushed Coarse aggregate for specific application and performance of normal weight concrete can be established. This would allow for a performance approach to classification of crushed coarse aggregates of different quarries and also used for comparison between crushed natural aggregate Of Different Quarry Sites with by the appropriate standards. The properties of fine natural aggregates were also determined in the mix design programme.

Category class two

In category class two, the Five Quarry Crushed Coarse aggregates were used to produce normal weight concrete and also comparison was made with the five different coarse aggregate mix of concrete. The research program devised is shown schematically in figure 8. For category class 1 and 2, tests were planned and carried out as detailed in the following sections.

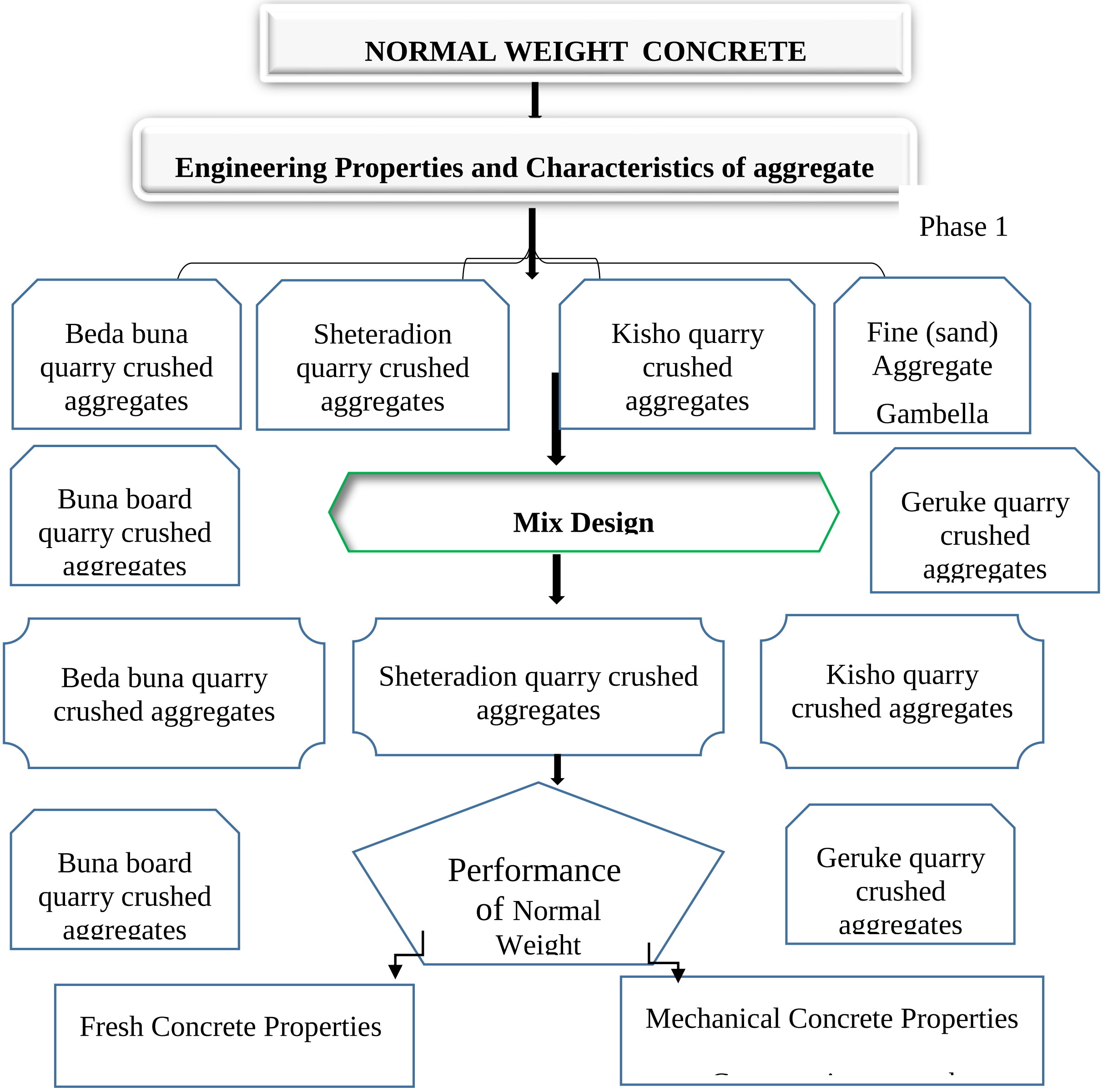

Figure 8: Research Programme

3.3 Experimental Work Procedures of Aggregate

3.3.1 Properties of Coarse Aggregate

The physical, mechanical and chemical properties of the coarse aggregate collected from the five different sources or locations of the stockpiles, hereinafter stated as sources named BBCCA, SCCA, KCCA, BB'CCA, and GCCA were determined in the laboratory according to the test methods specified in table 2 **in Appendix C1.** For each type of aggregate according to AASHTO T 2, and ASTM D 75 the filed sample were taken 25kg per source of aggregate and also reduced to test sample with compliance of AASHTO T 248. All aggregate quality tests were shown in appendix B,C1 and C2.

3.3.2 Sieve Analysis

The grading is determined by ASTM C 136, "Sieve or Screen Analysis of Fine and Coarse Aggregates." A sample of the aggregate is shaken through a series of sieves nested one above the other in order of size, with the sieve having the largest openings on top and the one having the smallest openings at the bottom

The gradations of aggregate were selected by considering the ASTM C-33 standard coarse aggregate gradation specifications as shown in (appendix B). In this study, aggregate size 20mm gradation was used as standard coarse aggregate gradation. The gradation of the aggregate was selected primarily based on the lower, average and upper values of the percentage weight passing through the sieves. A plot of the low, average and upper values of the aggregate size 20mm gradation is shown in (appendix C1,C2). During this test; the laboratory sample was taken by reducing the filed sample with sample Riffling technique.

Figure 9:Sieve analysis sample

3.3.3 Specific Gravity & Absorption (ASTM C 127-01 and ASTM C 128-01)

Tests for the specific gravity and absorption characteristics of aggregates have long been used to aid in determining batch quantities for concrete. Test methods for finding specific gravity of aggregates are described in ASTM C-127&AASHTO T 85, "Specific Gravity and Absorption of Coarse Aggregate," are the accepted test procedures. The particle densities and water absorption are calculated according to the following equation provided in the standard:

3.3.4 Bulk density (unit weight)

The bulk density of the aggregate was determined according to ASTM C29 & AASHTO T019. In the test, a test cylinder of known volume is used and the mass of aggregate required to fill the cylinder is determined from the difference in mass between filled and empty cylinder.

Figure 10:The Bulk Density of the Coarse Aggregate Test

The bulk density (previously unit weight and sometimes called dry-rodded unit weight) of an aggregate is the mass of the aggregate divided by the volume of particles and the voids between particles. The method most commonly used requires placing three layers of oven-dry aggregate in a container of known volume, rodding each layer 25 times with a tamping rod, leveling off the surface, and determining the mass of the container and its contents. The mass of the container is subtracted to give the mass of the aggregate, and the bulk density is the aggregate mass divided by the volume of the container.

3.3.5 Moisture Content

Moisture Content of coarse aggregate was determined by ASTM C 566, "Total Moisture Content of Aggregate by Drying," by measuring the mass of a sample of the aggregate representative of the moisture content in the supply being tested, drying the sample and obtaining the mass again. In the test, about 2 kg of an aggregate sample is oven dried at 105'C for 24 hours and from the difference in weight before and after drying, the moisture content is determined.

3.3.6 Aggregate Crushing Value

The aggregate crushing value is determined according to BS 812-110:1990. In the test, aggregates of sieve size between 10 mm and 14 mm are placed in a steel cylinder and subjected to a load of 400 KN though a plunger as shown in Figure 3.8. This action crushes the aggregate to a degree which is dependent on the crushing resistance of the material. This degree is assessed for the amount of crushed aggregate passing through sieve size 2.35 mm and is taken as a measure of the aggregate crushing value (ACV).

Figure 11: Aggregate Crushing Value (ACV) and test sample

3.3.7 Aggregate Impact Value

The AIV test was done according to BS 812-112:1990. The AIV value gives a relative measure of the resistance of the aggregate to sudden shock or impact. This test has been designed to evaluate the toughness or the resistance of stones, aggregate to breaking down under repeated application of impact.

The test samples are prepared by sieving coarse aggregates with sieve size 10 mm and 14 mm, and collecting samples passing through the 10 mm sieve and retained on the 14 mm sieve. The test specimen is then compacted, in a proper procedure, in an open steel cup. The specimen is then subjected to some standard impacts from a dropping weight as shown in figure 3.9 This action breaks the aggregate to a degree which is dependent on the impact resistance of the material. This degree is assessed for the amount of crushed aggregate passing through sieve size 2.35 mm and is taken as a measure of the aggregate crushing value (AIV).

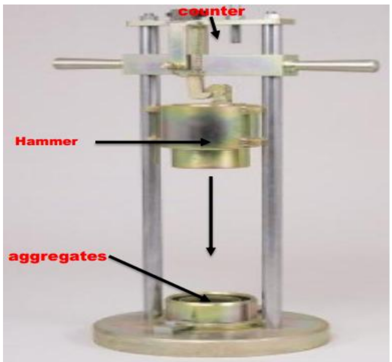



Figure 12:Aggregate Impact Value test

3.3.8 Los Angeles Abrasion Test

The LA test is carried out according to (ASTM C 131-89) & (AASHTO T 96-94) for Small-Size Coarse Aggregate. The test samples are prepared by sieving coarse aggregates and collecting samples passing through sieve size 14 (12.5) mm and retained in sieve size 10 (9.5) mm. Minimum of 5 kg of the test samples were used for each type of coarse aggregate the test. The test samples are rolled with steel balls in a rotating drum, shown in Figure 3.10 for 500 revolutions at a constant speed between of 31 and 33 rpm. After rolling is completed, the quantity of material retained on sieve 1.7mm (#12) gm. Size sieve is determined.

Figure 13: Abrasions and Impact in the Los Angeles Machine

3.3.9 Soundness of Aggregates by Use of Sodium Sulphate (ASTM C 88-99a)

The test is carried out according to ASTM C88 Soundness of Aggregates by Use of Sodium Sulphate. The Sulphate soundness test is one of the most widely used tests for the prediction of freezing and thawing durability of an aggregate test. The test is conducted by ASTM C88 or AASHTO T 104, and with sodium sulfate. Freezing and thawing cycles are simulated by immersing the aggregate in a sulfate solution, drying the aggregate, and then re-immersing the aggregate in the sulfate solution. The ranges of mass loss allowed in specifications vary from agency to agency with the type of sulfate used. Typical limits are 12 and 18 percent loss for sodium and magnesium sulfate, respectively. In this study for the five quarry crushed aggregates test were conducted.

Figure 14:Soundness Tests by Sulphate

3.3.10 Properties of Fine Aggregate

Properties and accepted test methods were discussed in this part include aggregate gradation; fine aggregate and fineness modules; relative bulk densities of wet, saturated surface dry, air-dry, and oven-dry aggregates; moisture absorption. The accepted test method for this study used was showed in table 2 appendix: A

3.3.11 Sieve Analysis; Gradation ASTM C136

The grading was determined by ASTM C136/C136M, "Sieve Analysis of Fine and Coarse Aggregates." A representative sample of the aggregate that has been properly prepared is shaken through a series of sieves nested one above the other in order of size, with the sieve having the largest openings on top and the one having the smallest openings at the bottom. Between three hundred and one thousand grams of material were used for each test.

Figure 15:A Series of Sieves Standard Test Apparatus

3.3.12 Fineness Modulus

Fineness modulus is often computed using the sieve analysis results. The fineness modulus is the sum of the total percentages coarser than each of a specified series of sieves, divided by 100. The specified sieves are the 4.75 mm, 2.36 mm, 1.18 mm, 600 μm, 300 μm, and 150 μm (No. 4, 8, 16, 30, 50, and 100). Note that the lower limit of the specified series of sieves is the 150 mm (No. 100) sieve and that the actual size of the openings in each larger sieve is twice that of the sieve in the following.

3.3.13 Relative density (specific gravity)

This test was conducted in accordance with ASTM C128, "Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate." Fine aggregate is dried to a constant mass at 100 to 110°C (212 to 230°F), cooled in air, and either moistened to at least 6 percent total moisture and sealed for 24 hours or immersed in water for 24 hours. The sample is stirred frequently until it approaches a free-flowing condition and then a portion is placed in a mold and tamped. If surface moisture is still present, the fine aggregate will retain its molded shape after the mold is lifted. Drying is continued with testing at frequent intervals until the tamped fine aggregate slumps slightly upon removal of the mold. This indicates that it has reached an SSD condition.

3.3.14 Absorption and surface moisture

The various moisture conditions in which an aggregate may exist have been described previously. Two of these, oven-dry and saturated surface-dry (SSD), are used as the basis for relative density calculations. Aggregates stockpiled on the job, however, are seldom in either of these states. Absorption is a measure of the total pore volume accessible to water and is usually calculated using the results from a relative density determination (ASTM C127; ASTM C128).

Absorption is computed as a percentage by subtracting the oven-dry mass from the saturated surface-dry mass, dividing by the oven-dry mass, and multiplying by 100.

Absorption $\% = \frac{\text{WSSD} - \text{WOD}}{\text{WOD}} * 100$

3.3.15 Total moisture content

Total moisture content is measured in accordance with ASTM C566, “Total Moisture Content of Aggregate by Drying,” by measuring the mass of a sample of the aggregate representative of the moisture content in the supply being tested, drying the sample, and obtaining the mass again.

Total moisture content % $= \frac{W - WOD}{WOD} * 100$

3.4 Experimental Work Procedures of Concrete

3.4.1 Mix Design

To see the effect of a variety of coarse aggregates, whose maximum size 20 mm were prepared and mix designs for concretes made with crushed aggregates of different properties were used. The coarse aggregate gradations employed using a max size of 20mm accordance with prevailing specifications by the ASTM C-33.

- BBC, SCCA, KCCA, BB'CCA AND GCCA coarse aggregate was used, thereby resulting in five mixes, which were designated as follows:
- Mix By Beda Buna Crushed Coarse Aggregate (BB'CCA),
- Mix By Sheteradion crushed Coarse Aggregate (SCCA) and
- Mix By Kisho crushed Coarse Aggregate (KCCA)
- Mix By Buna Board crushed Coarse Aggregate (BB'CCA)
- Mix By Geruke crushed Coarse Aggregate (GCCA)
- Natural sand conforming to specifications by the ASTM C-33 Aggregate for Portland Cement Concrete: Fine Aggregate was used in all mixes the same source.
- Cement: Type I, ASTM C 150, with a relative density of 3.15
- The methods and procedures used in testing these materials, as well as those employed in formulating the mix designs adopted in this study, are then outlined.

Each mix of concrete is composed of crushed or natural coarse aggregate, natural sand, ordinary Portland cement, and water.

Mix designs were thus created for each of three different varieties of coarse aggregates. The summarised mix design and the procedure were presented as follows according to ACI mix design methods;

1. **Properties of aggregates used in the analysis**

Table 5: Properties of aggregate samples used for the mix design

Engineering Properties of Aggregate		Crushed coarse aggregates					Standard Specification
		BBCCA	SCCA	KCCA	BB'CCA	GCCA	
1	Specific Gravity (SSD)	2.805	2.828	2.855	2.807	2.855	ASTM C 127 2.4-2.9
2	Water Absorption (%)(SSD)	0.96	0.87	0.82	1.17	0.78	ASTM C 127 0.2% to 4%
3	Dry-Rodded Unit Weight (kg/m3)	1539.67	1562.06	1580.77	1527.79	1573.08	ASTM C 29M -97 1200-1750

4	Aggregate Impact Value (%)	14.97	14.07	13.79	16.94	14.03	BS812-112:1990 ≤45
5	Aggregate Crushing Value (%)	16.59	15.41	15.20	19.52	12.65	BS812-110:1990 ≤35
6	Flakiness index (%)	21	19	17	24	22.06	ASTM C 131 25-50
7	Sodium soundness (%)	2.6%	2.4%	2.2%	2.9%	2.3%	ASTM C88-90 ≤12

Table 6: Properties of aggregate samples used for the mix design

Properties of fine aggregate				
			Standard Specification	
1.	Unit weight (kg/m3)	1498	ASTM C -29	1520 – 1680
2.	Fineness modulus	2.54	ASTM C 136	2.2-3.1
3.	Specific gravity	2.595	ASTM C128	2.30 to 2.90
4.	Absorption, %	1.94	ASTM C128	0.2 to 2
5.	Free moisture content, %	1	ASTM C70-79	2 to 6
6.	Loose unit weight (Kg/m3)	1,394.2	ASTM C -29	1520 – 1680
7.	Specific gr. Of Cement (O.P.C)	3.15	ASTM C 150	

2. **Mix design procedure used in this research as per ACI 211.1-91**

Beda buna Crushed Coarse Aggregate (BBCCA), Sheteradion Crushed Coarse Aggregates (SCCA) , Kisho Crushed Coarse Aggregate (KCCA) ,Buna Board Crushed Coares Agregates (BB’CCA)And Geruke Crushed Coarse Aggregates (GCCA) sample (Designation of the samples is given in APPENDIX C-1.1)

Step 1: slumps

Slump = (25 – 100 mm) ………………… (ACI 211.1-91 Table 6.3.1 Appendix C)

Step 2: Maximum size of aggregate

Maximum size is fixed to be 20mm.

Step 3: Target mean strength calculation

f'cr, = f' c + 8.5 f'cr, =25+8.5=33.5MPa …….. (ACI-318M; Table 5.3.2.2 Appendix C)

Step 4: Water/cement ratio

For 25MPa W/C ratio is 0.5

Step 5: Mixing water amount

For maximum size of aggregate of 20mm, slump 25 to 100mm (minimum range) and non-air entrained concrete the mixing water requirement according to ACI.211.1-91

Mixing water amount = 190 Kg/M^3 … (ACI 211.1-91; Table; a1.5.3.3 Appendix C)

Approximate amount of air, = **2 %**(ACI 211.1-91; Table; a1.5.3.3 Appendix C)

Step 6: Cement Amount

Cement content = Mixing water amount/ W/C ratio

180/0.5=**360** Kg/m^3

Step 7: Coarse aggregate amount

For maximum size aggregate =20mm and sand fineness modulus of 2.54, the dry bulk volume can be interpolated between fineness modulus of 2.4 and 2.6 that is

2.40	2.54	2.60
0.66	X	0.64

$$X = \frac{(0.66-0.64)}{(2.40-2.60)}(2.54-2.40) + 0.66$$

$\underline{= 0.646 \sim \mathbf{0.65}}$ ….. (ACI 211.1-91 Table 6.3.6 Appendix C)

Step 7.1 (unit weight for Beda Buna quarry site is 1539.67)

Step 7.1 for BBCCA(1539.67)

Coarse aggregate amount = 0.646***1539.67**=994.63 kg/m3 But **1539.67** kg/m3 is air dry bulk unit weight, and it has to be adjusted to air dry condition and back to SSD by dividing by total moisture and multiplying by absorption respectively. i.e.

Coarse aggregate $=\frac{W_{SSD}}{TM} * \text{Absorption} = [\frac{994.63}{(1+(\frac{0.61}{100})}*(1+\frac{0.959}{100})]$ = **998.1 kg/m³**

Step 7.2 for unit weight for Sheteradion quarry site is 1562.06)

Coarse aggregate amount = 0.646*1562.06=1009.1 kg/m3 But 1562.06 kg/m3 is air dry bulk unit weight, and it has to be adjusted to air dry condition and back to SSD by dividing by total moisture and multiplying by absorption respectively. i.e.

Coarse aggregate $=\frac{W_{SSD}}{TM} * \text{Absorption} = [\frac{1009.1}{(1+(\frac{0.55}{100})}*(1+\frac{0.865}{100})]$ = **1012.26 kg/m³**

Step 7.3 for unit weight for Kisho quarry site is 1580.77)

Coarse aggregate amount = 0.646***1580.77**=1021.18 kg/m3 But **1580.77** kg/m3 is air dry bulk unit weight, and it has to be adjusted to air dry condition and back to SSD by dividing by total moisture and multiplying by absorption respectively. i.e.

Coarse aggregate $=\frac{W_{SSD}}{TM} * \text{Absorption} = [\frac{1021.18}{(1+(\frac{0.52}{100})}*(1+\frac{0.820}{100})]$ = **1024.23 kg/m³**

Step 7.4 for buna board (unit weight for buna board quarry site is 1527.79)

Coarse aggregate amount = 0.646***1527.79**=986.95kg/m3 But **1527.79**kg/m3 is air dry bulk unit weight, and it has to be adjusted to air dry condition and back to SSD by dividing by total moisture and multiplying by absorption respectively. i.e.

Coarse aggregate $=\frac{W_{SSD}}{TM} * \text{Absorption} = [\frac{986.95}{(1+(\frac{0.74}{100})}*(1+\frac{1.17}{100})]$ = **991.16 kg/m³**

Step 7.5 Geruke (unit weight for Geruke quarry site is 1573.08)

Coarse aggregate amount = 0.646*1573.08=1016.209 kg/m3 But 1573.08 kg/m3 is air dry bulk unit weight and it has to be adjusted to air dry condition and back to SSD by dividing by total moisture and multiplying by absorption respectively. i.e.

Coarse aggregate $=\frac{W_{SSD}}{TM} * \text{Absorption} = [\frac{1016.209}{(1+(\frac{0.498}{100})}(1+\frac{0.7833}{100})]$ = **1014.22 kg/m³**

Step 8: Fine aggregate amount

Step 8.1 for Beda Buna quarry site

Fine aggregate amount = 2.595[1000-(180+$\frac{360}{3.15}$+$\frac{998.1}{2.805}$+50] = **778.20 kg/m³**

Step 8.2 for Sheteradion quarry site

Fine aggregate amount = 2.595[1000-(180+$\frac{360}{3.15}$+$\frac{1012.26}{2.828}$+50] = **772.72 kg/m³**

Step 8.3 for Kisho quarry site

Fine aggregate amount = 2.595[1000-(180+$\frac{360}{3.15}$+$\frac{1024.23}{2.855}$+50] = **770.62 kg/m³**

Step 8.4 for buna board quarry site

Fine aggregate amount = 2.595[1000-(180+$\frac{360}{3.15}$+$\frac{991.16}{2.807}$+50] = **785.28 kg/m³**

Step 8.5 for Geruke quarry site

Fine aggregate amount = 2.595[1000-(180+$\frac{360}{3.15}$+$\frac{1014.23}{2.855}$+50] = **779.71 kg/m³**

Step 9: Moisture correction

Table 7: Moisture Correction for the five crushed quarry coarse aggregates Mix Design

Ingredients	Estimated quantity(Kg)	Absorption (%)	Absorbed water(Kg)	Natural moisture (%)	N.M.C (Kg)	Adjusted quantity (Kg)
Moisture correction for BBCCA Mix design						
Water	180	_	_	_	_	182
Cement	360	_	_	_	_	360
C. Aggregate	998.1	0.959	12.58	1.00	9.981	1000.7
Air content	_	_		_	_	_
F. Aggregate	778.20	1.94	15.56	1	7.782	785.98
Total	2316.3					2328.68
Moisture correction for SCCA Mix design						
Water	180	_	_	_	_	174.57
Cement	360	_	_	_	_	360
C. Aggregate	1012.25	0.865	12.51	1.00	10.12	1014.64
Air content	_	_		_	_	_
F. Aggregate	772.72	1.94	15.45	1	7.72	780.45
Total	2324.97					2329.66
Moisture correction for KCCA Mix design						
Water	180	_	_	_	_	174.56
Cement	360	_	_	_	_	360
C. Aggregate	1024.23	0.820	12.5	1.00	10.24	1026.49
Air content	_	_		_	_	_
F. Aggregate	770.62	1.94	15.4	1	7.70	778.32
Total	2334.85					2339.37
Moisture correction for BB’CCA Mix design						
Water	180					175.24
Cement	360					360
C. Aggregate	991.16	1.17	13	1.00	9.91	994.25
Air content				_		

F. Aggregate	785.28	1.94	15.7	1	7.85	793.13
Total	2316					2323
Moisture correction for GCCA Mix design						
Water	180					174.2
Cement	360					360
C. Aggregate	1011.14	0.78	12.1	1.00	10.11	1013.13
Air content				_		
F. Aggregate	779.71	1.94	15.58	1	7.79	787.50
Total	2331					2335

Step 10 Lab trial batching

Table 8: Total quantities of materials required for the Mix Design

Types of aggregate		Water (Kg)	Cement (Kg)	Coarse Aggregate (Kg)	Fine Aggregate (Kg)	Total (Kg)
BBCCA	quantity (M^3)	182	360	1000.7	785.98	2328.68
	quantity (Per 9 mold)*	5.53	10.94	30.39	23.87	70.73
SCCA	quantity (M^3)	174.57	360	1014.64	780.45	2330
	quantity (Per 9 mold)	5.30	10.94	30.82	23.71	70.77
KCCA	quantity (M^3)	174.56	360	1026.49	778.32	2339
	quantity (Per 9 mold)	5.30	10.94	31.18	23.64	71. 06
BB'CCA	quantity (M^3)	175.24	360	994.25	793.13	2322
	quantity (Per 9 mold)	5.32	10.94	30.2	24.1	70.56
GCCA	quantity (M^3)	174.2	360	1013.13	787.50	2335
	quantity (Per 9 mold)	5.29	10.94	30.77	23.92	70.92
***=(0.15*0.15*0.15)*9=0.030375**						

3.4.2 Tests on Fresh Concrete and Hardened Concrete

1. **Fresh Concrete**

A. Slump

The test was performed by following ASTM C 143/C Standard Test Method for Slump of Hydraulic-Cement Concrete. A 30CM. Tall slump cone was filled with concrete in 3 equal layers. Each layer was rodded 25 times by a 5/8-in. Tamping rod. After the cone was filled, all excess concrete was stricken from the top. The cone was then lifted straight up, and the vertical displacement of the concrete was measured from the original top of the cone.

Figure 16: Scientific Standards for Slump Test Results.

Figure 17:Measuring Slump of Fresh Concrete Mix

B. Casting

To cast the required number of specimens, 45 Cube mix was used. The concrete was cast into five different kinds of a mix with (150mm*150mm*150mm) cubical specimens. The cubical mold was used for testing of compressive strength at 7th 14th and 28th with water immersion curing technique. Twenty-four hours after casting, the specimens were demanded, labeled, and placed in a mixture of water at room temperature to cure.

Figure 18:Typical 150 Mm Cube Mould

2. Hardened concrete

Compressive Strength of Concrete

Compressive strength tests were performed on 150 mm concrete cube specimens at the ages of 7, 14 and 28 days according to BS EN 12390-3:2009. The concrete cube specimens were tested in the 300 KN Denison Compression Machine as shown in Figure 3.16 at a loading rate of 200KN/min. The average of the three specimens was taken as the compressive strength of the concrete.

Figure 19:Compression Test Machine And Test Sample

CHAPTER FOUR

RESULTS AND DISCUSSION

4. Projects Concrete Aggregates Evaluation

Natural sand was commonly used fine aggregate for concrete and also crushed rock aggregate was the most widely used coarse aggregate for concrete

4.1 Natural Sand

Gradation Test

The evaluation of fine aggregate gradation was done using ES C.D3.201 and cross-checked with ASTM C 33. Annex D2 and Annex C1 this all shows that study sand sample gradation graph line is in between the maximum and the minimum graph lines. It means that this sand samples are within the limit of the standard and well graded. Also ES standard specified the fineness modulus (FM) of fine aggregate should be in between 2 and 3.5 with the tolerance of ±0.2. The result showed that the sand sample (Gambela sand) satisfied this limitation by scoring 2.54. Therefore the sand sample evaluated in this research fulfill ES, ASTM and BS specifications in all sieve sizes so that, gradational wise, it can be used in constructions concrete works confidently.

The most desirable fine-aggregate grading depends on the type of work, the richness of the mixture, and the maximum size of coarse aggregate. In general, if the water-cement ratio is kept constant and the ratio of fine-to-coarse aggregate is chosen correctly, a wide range in grading can be used without measurable effect on strength. However, the best economy will sometimes be achieved by adjusting the concrete mixture to suit the gradation of the local aggregates. Fine-aggregates grading is within the limit. Therefore, those fine aggregates are gradation perspective satisfactory for concrete works.

4.2 Fine Aggregates

The fine aggregate samples were selected collected from Jimma Town aggregate crushing site in the different quarry sites of the town predominantly from the crushers site in which their production or grinding is for building projects.

1. **Sieve Analysis**

Table 9:Grain Size Analysis of Fine Aggregate Samples (ASTM C 33/AASHTO M 6).

Sieve No	Sieve Dia. (mm)	Percentage passing	ERA and *ASTM C 33*		Remark
	12.5	100	lower	upper	
	9.5	100	100	100	
4	4.75	95.84	95	100	Passed
8	2.36	90.4	80	100	Passed
16	1.18	77.52	50	85	Passed
30	0.6	57.71	25	60	Passed
50	0.3	21.81	10	30	Passed
100	0.15	3.19	2	10	Passed
pan		0.00	0	0	

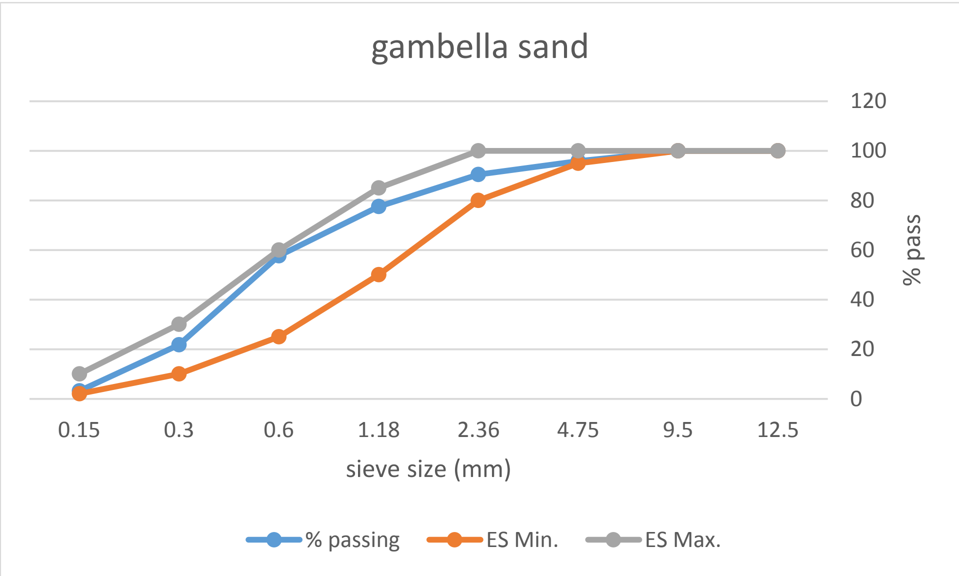

Figure 20:Average Grading Curve Test for Fine Aggregates

1. Fineness Modulus

According to the requirement of ASTM C33/C33M for sands used in concrete, the fineness modulus shall not be less than 2.30 and more than 3.1. Fineness modulus is often computed using the sieve analysis results. The fineness modulus is the sum of the total percentages coarser than each of a specified series of sieves, divided by 100. The coarser the aggregate, the higher fineness modulus. The result of the fineness modulus of the fine aggregate samples s summarized as follows;

Table 10:Calculation of Fineness Modulus of Fine Aggregate

Sieve size Total	Percent retained (X1)	100-X	X
9.5 mm (3/8 in.)	0.00		
4.75 mm (No. 4)	4.16	100-95.84	4.16
2.36 mm (No. 8)	5.44	100-90.4	9.6
1.18 mm (No. 16)	12.88	100-77.52	22.48
600 mm (No. 30)	19.81	100-57.71	42.29
300 mm (No. 50)	35.9	100-21.81	78.19
150 mm (No. 100)	18.62	100-3.19	96.81
Sum $\sum X$			253.53
FM=$\frac{\sum X}{100} = \frac{253.53}{100}$ **= 2.54**			
ASTM C33/C33M	Not less than 2.31 and greater than 3.1		

1. Compacted Unit Weight

The compacted bulk density measures the volume that the aggregate will occupy in concrete. The result for the compacted bulk density is shown in table 4.9. According to ASTM C-*33*, the compacted bulk density of aggregates used for normal weight concrete ranges from 1200 to 1760kg/m3. The value of the compacted bulk density of fine aggregate is within the specified limit as shown in table 4.9. This indicates that the fine aggregate is stable for construction work.

Table 11:The Value of the Compacted Bulk Density of Fine Aggregate.

Description		Trial No			Average
		1	2	3	
Unit Weight Kg/m3	(B – A) / C	1498	1498	1497.8	1498 kg/m3
ASTM C29/C29M limit	To 1760 kg/m3				

1. **Relative Density and Absorption of Fine Aggregate**

Table 12:Specific Gravity of the Fine Aggregate Samples

No.	Description	Trial	ASTM
1	Relative density (specific gravity)	Test 1	C-128
	Apparent Specific Gravity	2.678	2.4 to 2.90
	Bulk Specific Gravity	2.546	2.30 to 2.90
	Bulk Specific Gravity (S.S.D basis	2.595	2.4 to 2.90
2	Absorption	1.94	0.2% to 2%,

Finer materials were less than sieve no. 200

Testing for material finer than the 75 µm (No. 200) sieve should be done by ASTM C 117 and ASTM C33. ASTM specification limits the amount of material passing the 75 µm (No. 200) sieve to 5% in fine aggregate. On Annex, C1 showed that the sand sample of Gambela fulfill the ASTM limitation.

Figuratively the sand sample of Gambela scored 2.41%. Therefore under ASTM and ES, the sand sample is practical in construction without the need of washing.

Water absorption

The absorption of aggregates should be determined according to ASTM C 128 so that the total water content of the concrete can be controlled and corrected using batch weights determination. The internal structure of an aggregate particle is made up of solid matter and voids that may or may not contain water. Fine aggregate will have absorption levels (moisture contents at SSD) in the range of 0.5% to 4%. However, Annex C1 showed that the water absorption amount of Gambela sand satisfied the limit which is 1.94%.

Specific gravity

The relative densities for fine aggregates are described in ASTM C 128 and BS 812: Part 2. The relative density of an aggregate may be determined on an oven dry basis or a saturated surface-dry (SSD) basis. Both the oven dry and saturated surface-dry relative densities may be used in concrete mixture proportioning calculations. From the above table and chart the relative density of the sand sample collected from a site is within the limit of a specification. The specification indicates that most natural aggregates have relative densities between 2.3 and 2.9. Laboratory data shows the relative density of the sand sample is 2.595. So that the sand sample satisfies the relative density specification.

Unit weight

The unit weight or bulk density of an aggregate is the mass or weight of the aggregate required to fill a container of a specified unit volume. The volume referred to here is that occupied by both aggregates and the voids between aggregate particles. The approximate bulk density of aggregate commonly used in normal-weight concrete ranges from about 1280 to 1920 kg/m3. Methods for determining the bulk density of aggregates is given in ASTM C 29 (BS 812: Part 2). In these standards, three methods are described for consolidating the aggregate in the container depending on the maximum size of the aggregate: rodding, jigging, and shoveling. The laboratory tests for unit weight was done for both compact and loose thus the result showed, figuratively, for both compact and loose thus the result showed 1498 kg/m3 and 1394.2 kg/m3 of the sand sample , so the sand sample is within the specification, so the sand sample of gambela is confident on unit weight.

Crushed Coarse Aggregate

Gradation

The grading or particle size distribution of an aggregate is determined by a sieve analysis test in which the particles are divided into their various sizes by standard sieves. The evaluation was made by ASTM C 136.

4.1 Aggregates

This chapter contains tabulations of all data recorded during the tests conducted, a discussion of all quality tests, as well as outlines of the subsequent calculations needed to translate test results into the properties of the aggregates. The average values obtained for each concrete mix on each testing date are also presented. Each such mix is assigned a three-character code identifying the type of the coarse aggregate used (BBCCA, SCCA , KCCA, BB'CCA, and GCCA).

The principal constituents of ordinary concretes are crushed rocks or gravels used as coarse aggregates and sands used as fine aggregates. Materials used in concrete usually need to be processed for Engineering properties and conforming to the designated specifications. It follows, therefore, that concrete will only become a quality material for construction when the ingredients are properly sourced and selected as well as when it is manufactured under a regulated standard and practice procedure.

4.1.1 Coarse aggregate

This section objective was to determine the Engineering properties of Crushed coarse Aggregate for the requirements of Concreting works around the Jimma Town**.** This study obtained five different sources of coarse aggregate samples conforming to the designated specifications was used and after that conducted the following laboratory tests on some of their properties to determine their fitness for use in producing concrete.

Table 13:Average Sieve Test Result for BBCCA

Aggregate type Size 20mm	Sieve size (mm)					
	37.5	25	19.5	12.5	9.5	4.75
BBCCA % passing	100	89.1	47.21	21.27	3.87	0.99
ASTM C-33 upper limits	100	100	85	40	15	5
ASTM C-33 lower limits	100	90	40	10	0	0

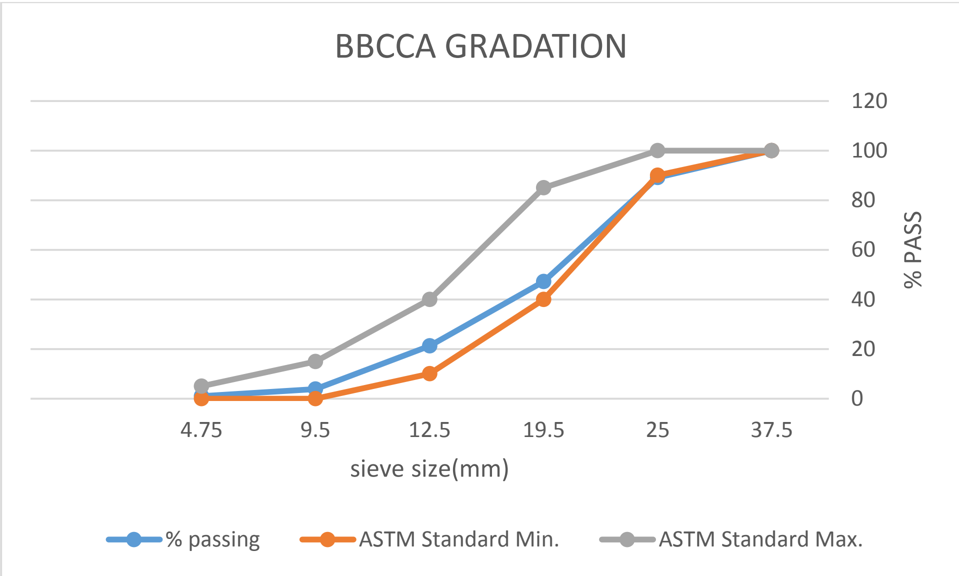

Figure 21:Average Gradation Curves for BBCCA

The results for average particle size distribution of beda buna crushed coarse aggregate are summarized and presented in table 13 and figure 21. It was observed that the beda buna Crushed coarse aggregate were fallen within limits specified by ASTM C-33 except for one sieve No (i.e., 25.0 mm 89.1). As shown in Table 13, the percentage passing sieve 19.5 through 4.75 were 47.21 and 0.99 which was meet the gradation specifications for ASTM C33 (85-40 and 5-0%) grading requirements for coarse aggregates. Also from the figure, it was seen that the percentage passing curve for sieve 19.5 through 4.75mm was slightly closer to the lower limits of ASTM C-33 and it indicated that the beda buna crushed coarse aggregate is coarser than fine content at this point.

Table 14:Average Sieve Test Result for SCCA

Aggregate type Size 20mm	Sieve size (mm)					
	37.5	25	19.5	12.5	9.5	4.75
SCCA	100	92.38	55.25	18.38	10.13	0.88
ASTM C-33 upper limits	100	100	85	40	15	5
ASTM C-33 lower limits	100	90	40	10	0	0

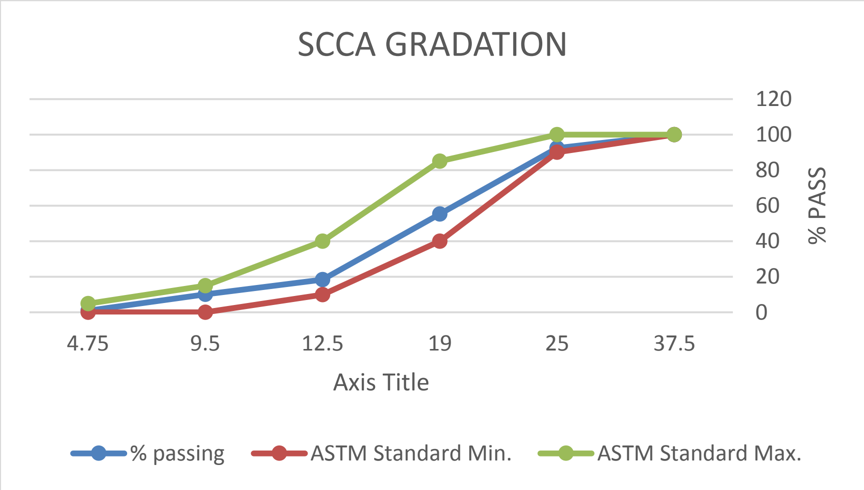

Figure 22:Average Gradation Curves for SCCA

Figure 22 Average Gradation Curve for SCCA

Table 12 shows the average test results of the sieve analysis of the Sheteradion Crushed coarse aggregate used; whereas figure 22 shows the graphical representation of the result. The result revealed that the Sheteradion Crushed coarse aggregate from the quarry was falling within the gradation specifications for ASTM C33/C 33M grading requirements for coarse aggregates except for one sieve No (i.e., 9.5 mm 10.13). As shown in Table 12, the percentage passing sieve 25.0 mm,19.5 mm ,12.5 mm ,through 4.75 were 92.38 , 55.25 ,18.38 and 0.88 which was meet the gradation specifications for ASTM C33 (100-90 , 5-40 , 40-10 and 5-0%) grading requirements for coarse aggregates. Also from the figure, it was seen that the percentage passing curve for sieve 25.0 mm through 12.5 mm and sieve size no 4.75 mm were slightly closer to the lower limits of ASTM C-33 and it indicated that the sheteradion crushed coarse aggregate is coarser on those points.

Table 15:Average Sieve Test Result for KCCA

Aggregate type Size 20mm	Sieve size (mm)					
	37.5	25	19.5	12.5	9.5	4.75
KCCA	100	90.1	45.8	20.8	7.47	0.98
ASTM C-33 upper limits	100	100	85	40	15	5
ASTM C-33 lower limits	100	90	40	10	0	0

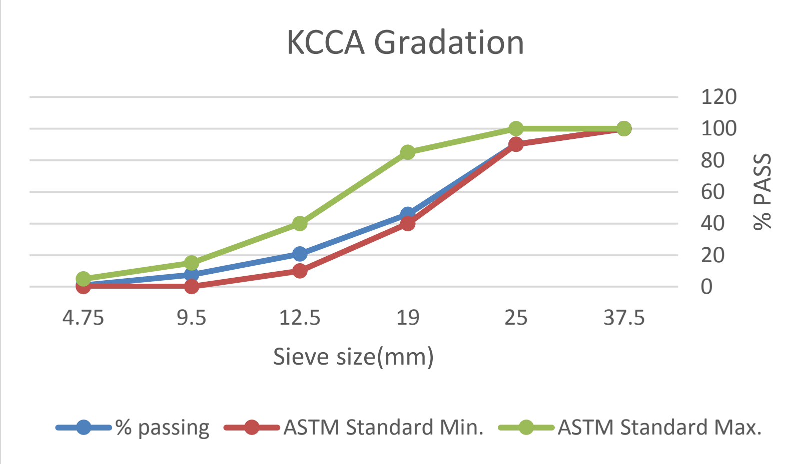

Figure 23:Average Gradation Curve for KCCA

Table 15 shows the average test results of the sieve analysis of the kisho crushed coarse aggregate used while figure 23 shows the graphical representation of the nature of the aggregate. It was observed that the kisho crushed coarse aggregate were fall within limits specified by ASTM C-33 standards except for one sieve No (i.e., 9.5 mm 7.47). As shown in table 13, the percentage passing on sieve No 9.5 mm was 7.47 %, which is somewhat between the upper and lower limits of ASTM C-33 and it indicated that kisho crushed coarse aggregate at this point were well graded.

It can be seen in figure 3.20 shows as the curves of the kisho crushed coarse aggregate were the percentage passing on sieve No 25.0 mm, 19.5mm,12.5mm and 4.75 mm was 90.1%,45.%,20.8% and 0.98% respectively which are closer to the lower limits means coarser on those points.

Table 16:Average Sieve Test Result for BB’CCA

Aggregate type Size 20mm	Sieve size (mm)					
	37.5	25	19.5	12.5	9.5	4.75
BB’CCA	100	87.49	43.52	21.28	6.83	0.77
ASTM C-33 upper limits	100	100	85	40	15	5
ASTM C-33 lower limits	100	90	40	10	0	0

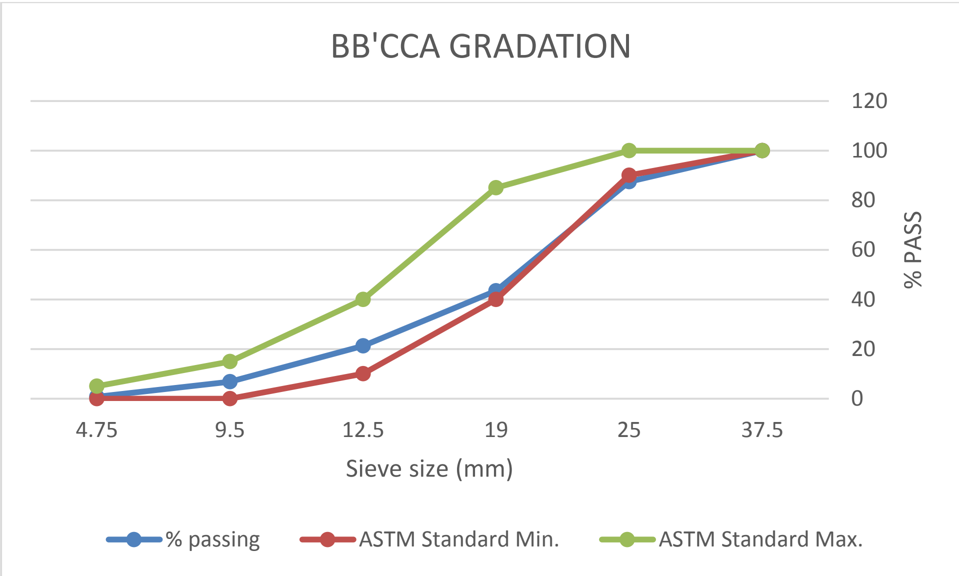

Figure 24:Average Gradation Curves for BB’CCA

The results for average particle size distribution of buna board crushed coarse aggregate are summarized and presented in table 16 and figure 24. It was observed that the buna board Crushed coarse aggregate were fallen within limits specified by ASTM C-33 standards except for one sieve No (i.e., 25 mm 87.49).As shown in Table 16, the percentage passing sieve 19.5 through 4.75 were 43.52 and 0.77 which was meet the gradation specifications for ASTM C33 (85-40 and 5-0%) grading requirements for coarse aggregates. Also from the figure, it was seen that the percentage passing curve for sieve 19.5 through 4.75 mm were slightly closer to the lower limits of ASTM C-33 and it indicated that the buna board crushed coarse aggregate is coarser than fine content at that point likewise sieve no12.5 mm and 9.5 mm were somewhat closer to the lower limit as well but the scale vary as compared to sieve no 4.75 mm and 19.5 mm .

Table 17:Average Sieve Test Result for GCCA

Aggregate type Size 20mm	Sieve size (mm)					
	37.5	25	19.5	12.5	9.5	4.75
GCCA	100	90.26	45.27	20.53	6.79	0
ASTM C-33 upper limits	100	100	85	40	15	5
ASTM C-33 lower limits	100	90	40	10	0	0

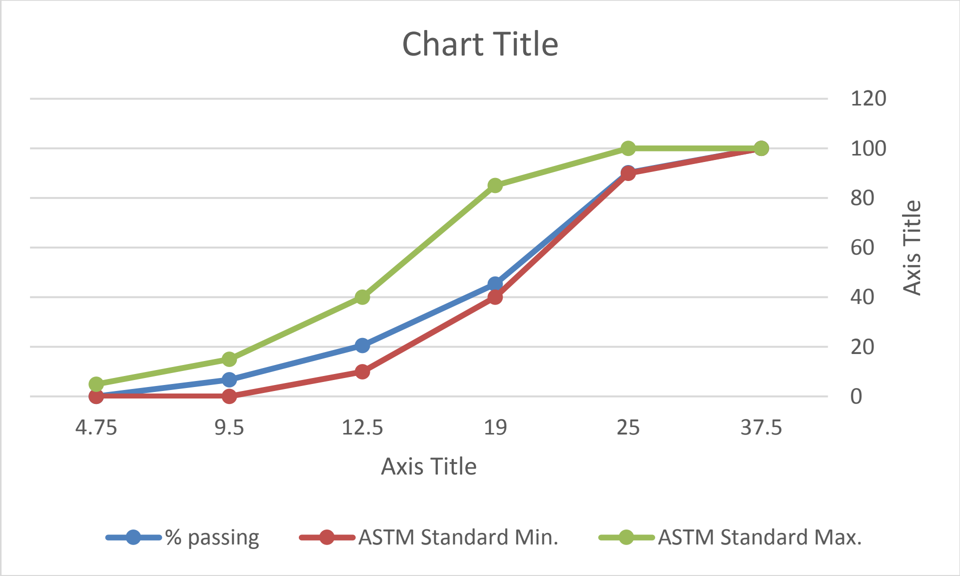

Figure 25:Average Gradation Curve for GCCA

Table 17 shows the average test results for the sieve analysis of the geruke crushed coarse aggregate used while figure 25 shows the graphical representation of the result. It was observed that the geruke crushed coarse aggregate was fallen within limits specified by ASTM C-33 standards. As shown in table 17, the percentage was passing on sieve No 25.0 mm were 90.26%, which is close to the lower limits and it seems coarser at this point. And also the percentage passing on sieve No 19.5,12.5, 9.5 and 4.75 were 47.27%,20.53%,6.79% and 0% respectively and it is indicated that slightly closer to the lower limit but somewhat the results are also not that much closer to the lower limit meaning the gradation curve clearly shows that the aggregate used in Geruke crushed coarse aggregate were coarser, but the finer content were also there.

Table 18:Average Engineering Properties of Coarse Aggregate

Engineering Properties of Aggregate		Crushed coarse aggregates					Standard Specification
		BBCCA	SCCA	KCCA	BB'CCA	GCCA	
1	Specific Gravity (SSD)	2.805	2.828	2.855	2.807	2.855	ASTM C 127 2.4-2.9
2	Water Absorption (%)(SSD)	0.96	0.87	0.82	1.17	0.78	ASTM C 127 0.2% to 4%
3	Dry-Rodded Unit Weight (kg/m3)	1539.67	1562.06	1580.77	1527.79	1573.08	ASTM C 29M - 97 1200-1750
4	Aggregate Impact Value (%)	14.97	14.07	13.79	16.94	14.03	BS812-112:1990 ≤45
5	Aggregate Crushing Value (%)	16.59	15.41	15.20	19.52	12.65	BS812-110:1990 ≤35
6	Flakiness index (%)	21	19	17	24	22.06	ASTM C 1 25-50
7	Sodium soundness (%)	2.6%	2.4%	2.2%	2.9%	2.3%	ASTM C88-90 ≤12

Specific gravity and water absorption:

Specific gravity and water absorption: Specific gravity and water absorption of aggregates under investigation were determined using ASTM standard C-127. The values of specific gravity and water absorption of aggregates investigated in this study have been graphically presented in Fig.1 and Fig.2 respectively. It is obvious from those figures that the specific gravity and water absorption of aggregates obtained from Jimma Town are similar to each other.

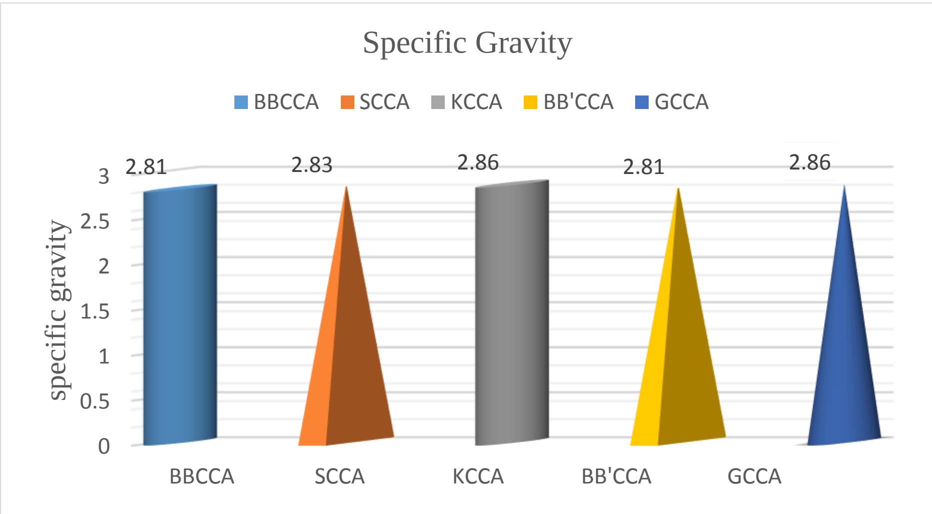

Figure 26:specific gravity of different aggregates

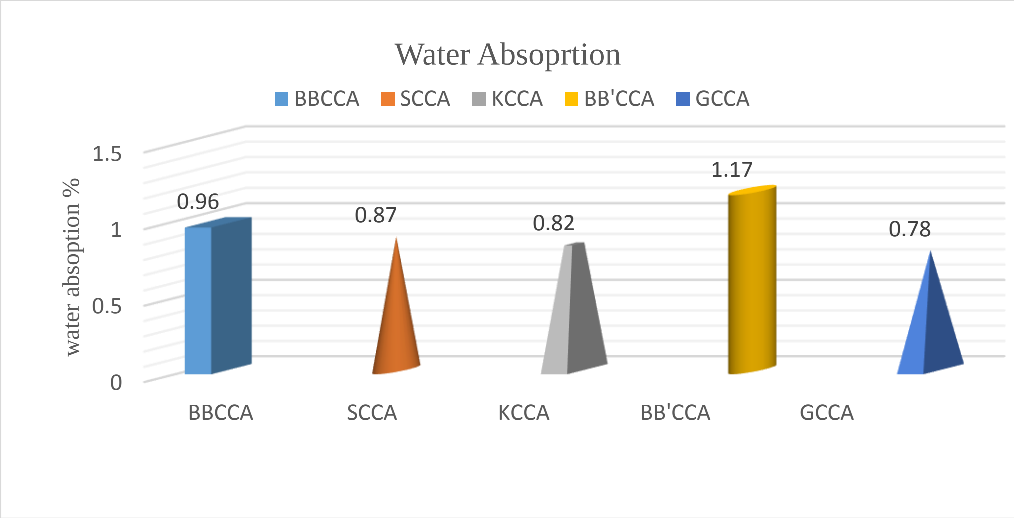

Figure 27:water absorption of different aggregates

Specific gravity and water absorption of aggregates under investigation were determined using ASTM standard C-127. The values of specific gravity and water absorption of aggregates investigated in this experimental study have been presented in Annex C2. It is evident from these above figures that the specific gravity and water absorption of aggregates obtained from five crusher sites can be used in building construction projects.

Comparison of specific gravity values of aggregates from crushers has shown that bulk and apparent specific gravity of crushed aggregates are within range of ASTM limitation. ACI stated concrete aggregates specific gravity should be between 2.3 and 2.9 as we can see from the table in Annex C2 the results are between 2.8 and 2.9.

The specific gravity of kisho quarry and geruke quarry exhibit the same result and followed by sheteradion quarry but beda buna and buna board exhibit more or less the same result which is 2.805 and 2.807 respectively.

Among the five coarse aggregate samples, sample five aggregate exhibited the lowest value of water absorption which was 0.78%. Similarly, a maximum value of water absorption was obtained with sample four aggregate which was 50 % greater than the water absorption of sample five. According to ACI range normal concrete water absorption capacity should be 0.5-4 so that, absorption point of view, all coarse aggregate samples are confident to use in concrete. Comparison of water absorption of the quarry sites which it is indicated in the figure, that buna board quarry site exhibit the highest recorded value which is 1.17 and followed by Buda buna which is 0.96, the others samples are also in the range satisfying the standard.

Unit Weight

Unit weight of aggregates under investigation was determined following ASTM C-29 procedure. The values of unit weight of different aggregates investigated under the scope of this study have been presented in Annex C2. Along with upper and lower limits as specified by ACI. The unit weight of natural concrete aggregates is in between 1280 to 1920 kg/m3. Correspondingly the laboratory results clearly indicate that unit weight of aggregate obtained from all five crusher sites are within ASTM range in numbers 1580.77 kg/m3, 1527.78 kg/m3, 1539.67 kg/m3, 1562.06 kg/m3 ,1573.08 kg/m3 for compact and 1460.85 kg/m3, 1410.02 kg/m3, 1421.18 kg/m3, 1448.18 kg/m3,1461.88 kg/m3 for loose respectively so when we observe the unit weight of all samples kisho quarry achieved the highest out of all other samples followed by geruke, sheteradion and Beda buna and the least unit weight was recorded by buna board which still under the standard. All five quarry coarse aggregate are confident on unit weight. In other words, the five crushers coarse aggregates have enough density for the concrete.

The results indicate that unit weight of aggregate obtained from Jimma Town quarry sites satisfies the ASTM Limits.

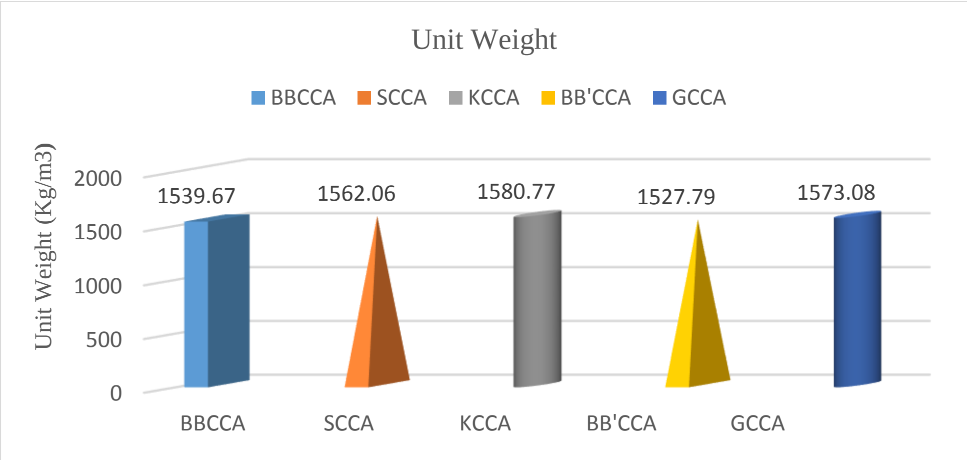

Figure 28:unit weight of different aggregates

Aggregate Impact Value (AIV) and Aggregate Crushed Value (ACV)

AIV is a relative measure of resistance to crushing of an aggregate when it is subjected to repetitive and impact loads. The comparison of AIV of five crusher aggregates with the Standard limitation of ASTM is shown in Annex C2. Aggregates obtained from a quarry and kisho crusher exhibited AIV lesser than other aggregates. The comparison of ACV of four crusher sites is shown in Annex C2. ASTM and BS standards both specified that concrete constituent aggregates ACV and AIV value should be less than 30%.The Five quarry site crushed coarse aggregate samples ACV and AIV laboratory evaluation shows that 16.585%, 14.965% for beda buna crusher crushed coarse aggregate, 15.41%, 14.07% for shenteradion crusher crushed coarse aggregate, 15.195%, 13.785% for kisho crusher crushed coarse aggregate, 19.515%, 16.935% for buna board crusher crushed aggregate and Geruke crusher crushed aggregate 12.65%, 14.03% respectively. From above results, all the quarry sites crushed aggregate ACV and AIV value are less than 30% so that all the quarry sites crushed aggregates can be used as the concrete ingredient in building construction.

Aggregate Impact value (AIV) and Aggregate Crushing value (ACV) of coarse aggregates play a major role in the development of resistance in hardened concrete against impact, and compressive loads, respectively and aggregate crushing value has great importance; greater is the ACV, more is the strength of concrete. ACV is a relative measure of the resistance of an aggregate to crushing when it is subjected to compressive forces. The results of this study concerning AIV and ACV of aggregates obtained from the five quarry sites crushed aggregate and commonly used aggregates in Jimma University building constructions indicate that aggregates from five quarry site crushers can be used in concrete with confidence. Out of five sample aggregates, the lowest value of AIV was yielded by sample five aggregate. AIV of others quarry sites aggregates were found to be in between 15 and 20%.

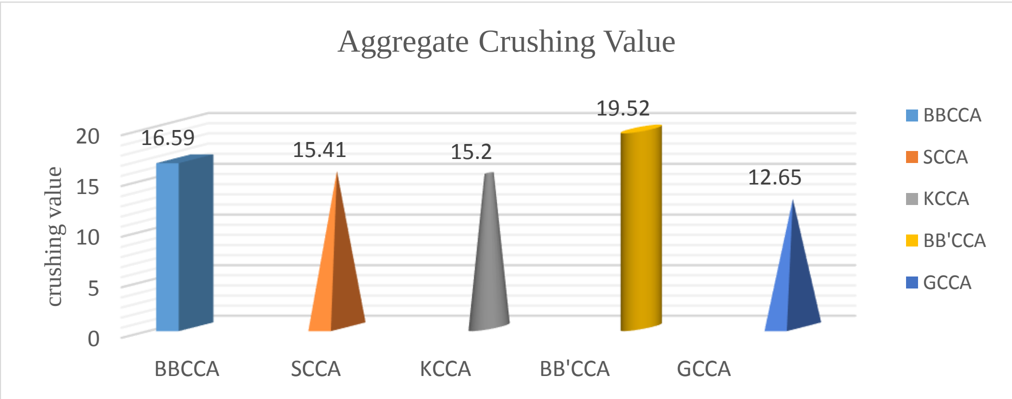

Figure 29:aggregate crushing value of different sources of aggregates

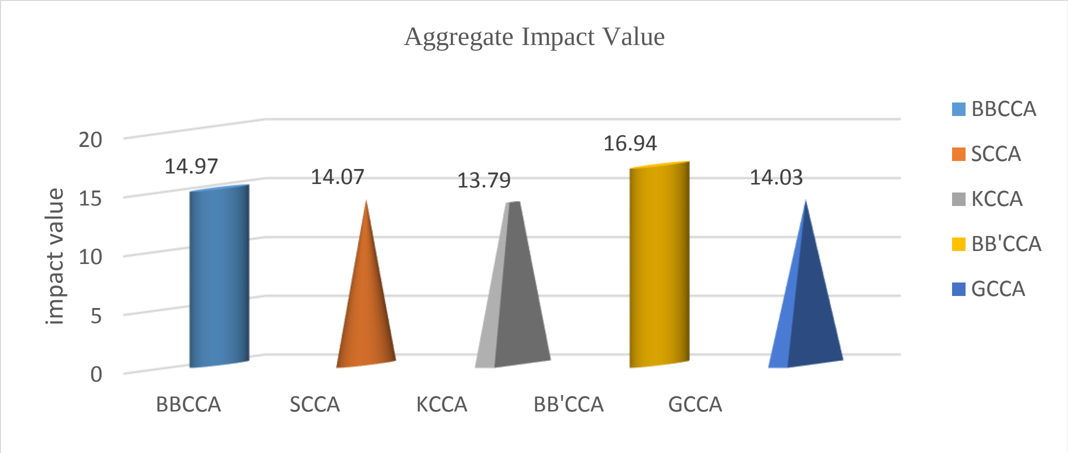

Figure 30:aggregate impact value of aggregates

Flakiness Index

Flakiness Index values of the five crushers crushed coarse aggregates were determined as per British Standard (BS 812-105.1). Flakiness index (FI) is a measure of the percentage weight of particles whose least dimension is less than 0.6 times the mean dimension. The values of FI of aggregates obtained from all five crushers are presented in Annex C2. It is observed that FI value of aggregates under investigation are within limits prescribed by ASTM and BS Standard. Which is FI < 35% and 40 %, respectively. The laboratory result showed that 21% for beda buna quarry crusher, 19% for shenteradion quarry crushed aggregate, 17% for sample kisho quarry crushed aggregate , 24% for buna board crushed aggregate and finally 22.06% for Geruke quarry crushed aggregate so that all the five crusher sites are within the limit of specification from all five sample kisho quarry crushed aggregate has lowest flakiness index.

Flat aggregate particles should be avoided or at least limited to about 15% by mass of the total aggregate. This requirement is equally important for coarse and for crushed fine aggregate since fine aggregate made by crushing stone often contains flat particles. Such aggregate particles require an increase in mixing water and thus may affect the strength of concrete, particularly in flexure, if the water-cement ratio is not adjusted.

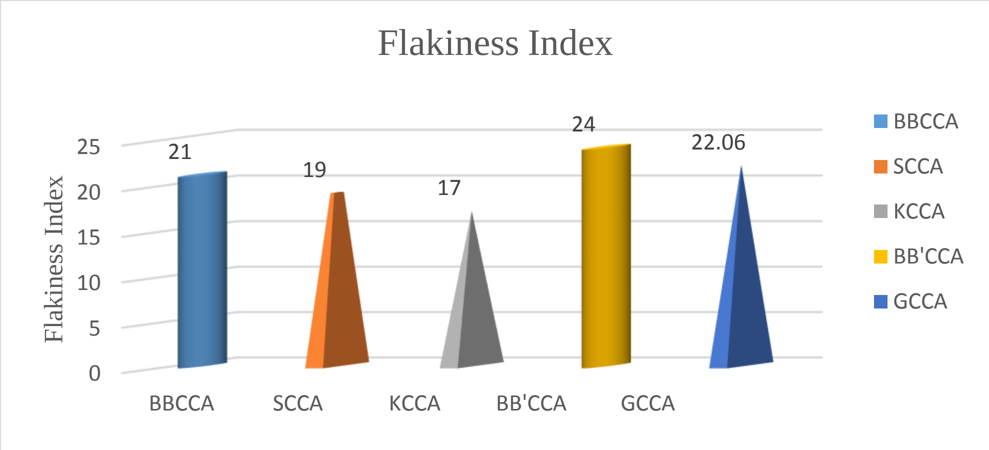

Figure 31:flakiness index of all the aggregates tested

Soundness of coarse aggregate

The soundness of aggregate gives its durability. It measures how resistant an aggregate is to chemical weathering. The five soaking and drying cycles were carried out in sodium sulfate soundness test. The result of the test samples varies from 2.2 to 2.9%. According to ASTM standard, the soundness value of coarse aggregate below the 12% is chemically sound (ASTM C88–05 by ASTM C33-01). Annex C2 shows that beda buna scores 2.6%, shenteradion 2.4%, kisho 2.2% ,buna board 2.9% and Geruke 2.3% soundness value far from the standard limitation 12% Sodium sulfate soundness test results indicated that the buna board crushed coarse aggregate had higher mass loss compared to other crushed coarse aggregate indicated on the figure (2.9% compared to 2.2% to 2.6%). The KCCA had a lower mass loss (2.2%) than the others and met the performance requirement of ASTM C33 which is 12%. This shows that all five coarse aggregates are chemically unsound and they can be used in concrete with confidence.

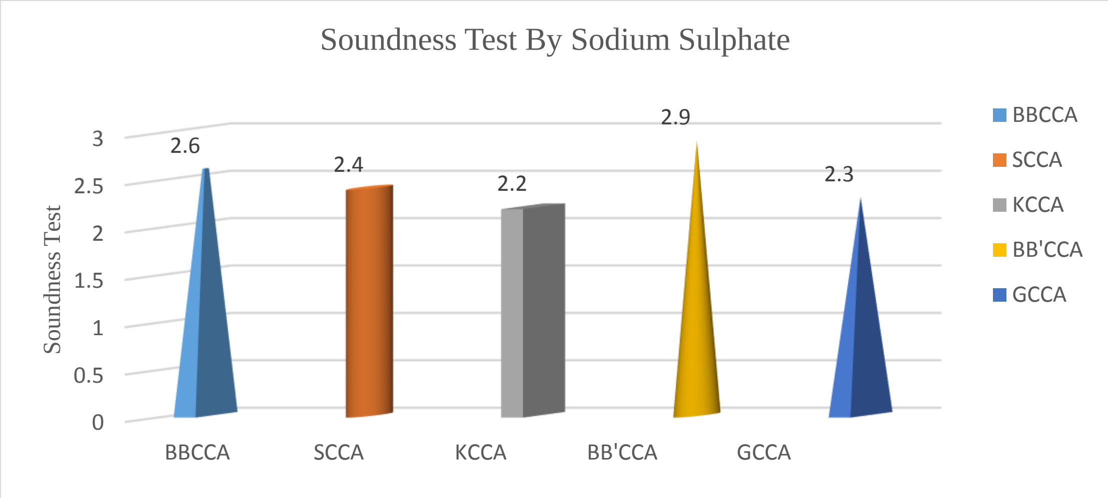

Figure 32:Soundness test by sodium sulfate

4.1.2 Mix Design

In this investigation, M 25 grade was considered and designed using a procedure by (ACI 211.1-91) with water cement ratio of 0.5. The calculation of quantities of ingredient requires for different concrete mixes are given in Appendix C1&2 and B.

Fresh Properties of Concrete Mixes

Workability Test

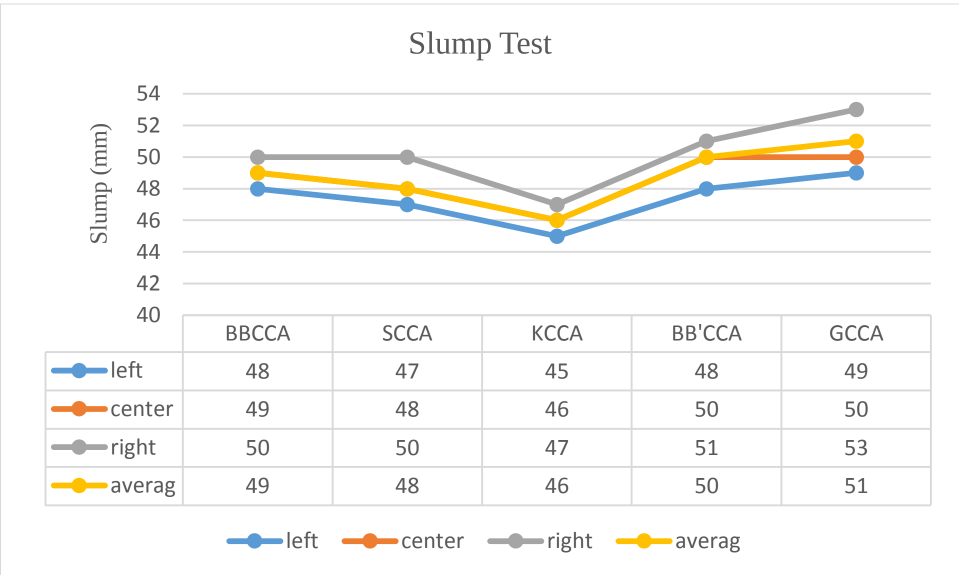

Figure 33:Slump test results of the five quarry samples.

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The tests were carried in five different mixes with the same W/C, cement type, and sand. Also, the measure was taken in three different points (right, center and left side) for each mixed sample. Workability of concrete mixes increased with geruke crushed coarse aggregate followed the buna board crushed coarse aggregates,beda buna,sheteradion and kisho respectively. The slump value of the concrete made using KCCA, SCCA, BBCCA, BB'CCA and GCCA are 46 mm, 48mm, 49mm, 50 and 51mm respectively, and for all concrete mix, the same water to cement ratio were used. Figure 33 shows a graphical representation of slump height. According to the result, the lowest slump obtained was 46 mm for kisho crushed coarse aggregate concrete mix and the highest slump was 51mm for geruke crushed coarse aggregate mix, for M 25 grade concrete mix.

Therefore, the workability was good and can be satisfactorily handled for all the mixes. There was no problem for the placement and compaction of fresh concrete.

4.1.3 Mechanical Properties of Hardened Concrete

Concrete Composition: For all types of concrete, locally available Ordinary Portland Cement (OPC) was used.Gambella sand was used as fine aggregates in all compositions of concrete. Different crushed coarse aggregates used to make concrete were Beda Board, Sheteradion, Kisho, Buna Board And Geruke. The maximum size of coarse aggregate used in concrete was 20mm. Water-cement ratio for all concrete mixes was kept as 0.5.

For each composition of concrete, three cylindrical specimens were tested. The value of each sample is given in table 17 Among five different concretes, concrete containing Gerukeaggregates exhibited the maximum value of compressive strength. The results depict that aggregates obtained from beda buna and buna board performed satisfactorily regarding compressive strength when compared to sheteradion and kisho aggregates.

Table 17 The Average Compressive Strength Test for Various Concrete Mixes

Mixes IDM	Days	Compressive strength in MPa	Rate of attainment of strength in %
BBCCA7D	7	23.73	94.92
BBCCA 14D	14	27.14	108.56
BBCCA 28D	28	33.8	135.2
SCCA7D	7	20.52	82.08
SCCA 14D	14	23.62	94.48
SCCA 28D	28	29.6	118.4
KCCA 7D	7	19.42	77.68
KCCA 14D	14	22.47	89.88
KCCA 28D	28	28.3	113.2
BB’CCA 7D	7	22.88	91.52
BB’CCA 14D	14	26.27	105.08
BB’CCA 28D	28	32.7	130.8
GCCA 7D	7	24.82	99.28
GCCA 14D	14	28.31	113.24
GCCA 28D	28	34.7	138.8

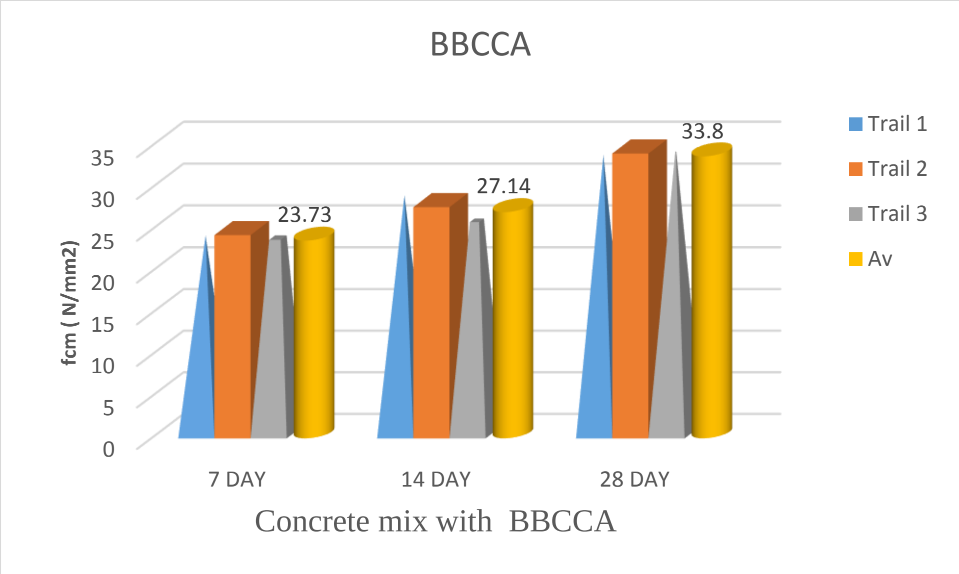

Figure 34:Concrete mix with BBCCA

Figure 34 Results of Compressive Strength for BBCCA Concrete Mixes

Figure 34 shows the development of compressive strength of concrete mixes with Beda Buna crushed coarse aggregate, under different types of curing environments for up to 28 days. The maximum 28-day strength of water cured specimen of about 33.8 MPa was achieved for mix BBCCA that contained all ranges of particles. The compressive strength of beda buna quarry gave the second highest value. The contributory aspect in gaining strength was that BBCCA aggregate made of angular shape Crushed aggregate and the highest among all the crushed aggregate shapes considered from other quarry sites .

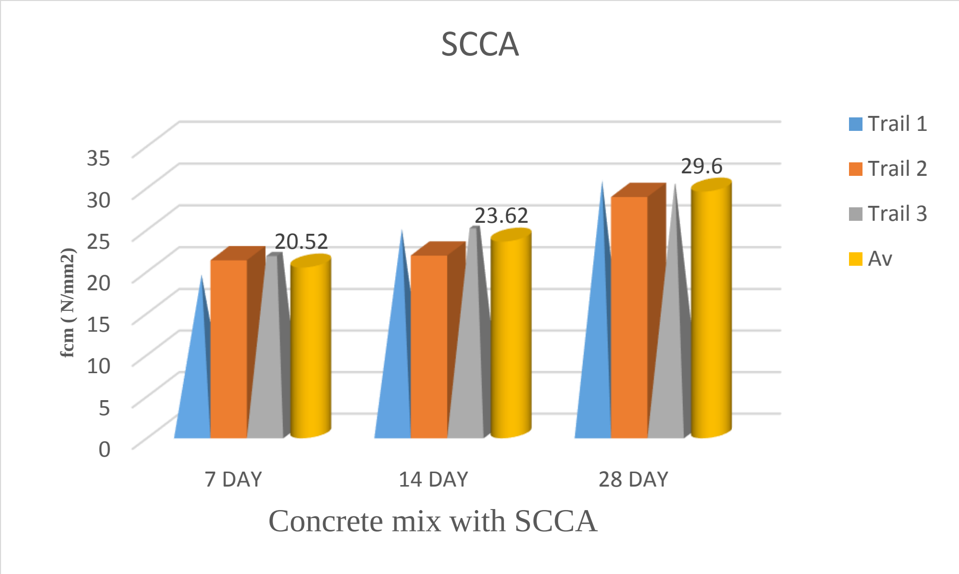

Figure 35:Concrete mix with SCCA

Figure 35 shows the development of compressive strength of concrete mixes with crushed coarse aggregate, under different types of curing environments for up to 28 days. The maximum 28-day strength of water cured specimen of about 29.6 MPa was achieved for mix SCCA that contained all ranges of particles. The second lowest value of compressive strength was obtained for the concrete prepared from SCCA; The reasons of strength reduction were found in this concrete that is because the properties of the aggregates used in this concrete were very low poor performance of the aggregates, so that the SCCA aggregates might not be able to make a proper bond with the cement paste due to that it showed lower compressive strength results. Which showed that the aggregates adopted from this quarry have not undergone for a proper gradation. Originally, flaky and elongated type of aggregates were obtained. This indicates that the aggregates of this quarry possess low strength as compared to the other quarries.

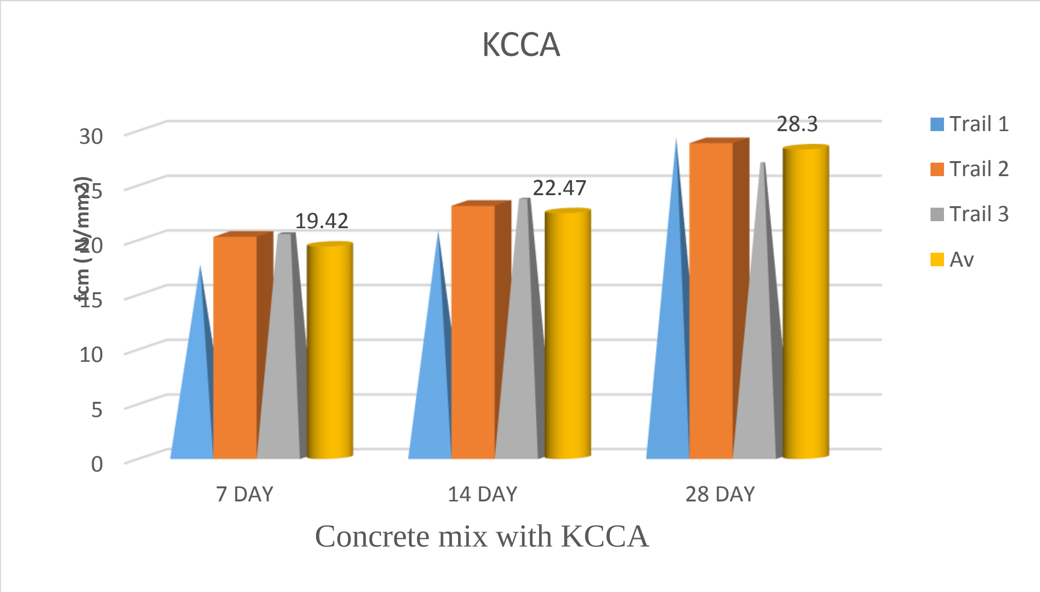

Figure 36: Concrete mix KCCA

Figure 36 shows the development of compressive strength of concrete mixes with crushed coarse aggregate, under different types of curing environments for up to 28 days. The maximum 28-day strength of water cured specimen of about 28.3 MPa was achieved for mix KCCA that contained all ranges of particles. The reasons for strength reduction were found in this concrete Like Sheteradion that is because the properties of the aggregates used in this concrete were a very low performance of the aggregates, so that the KCCA aggregates might not be able to make a proper bond with the cement paste due to that it showed lower compressive strength results.

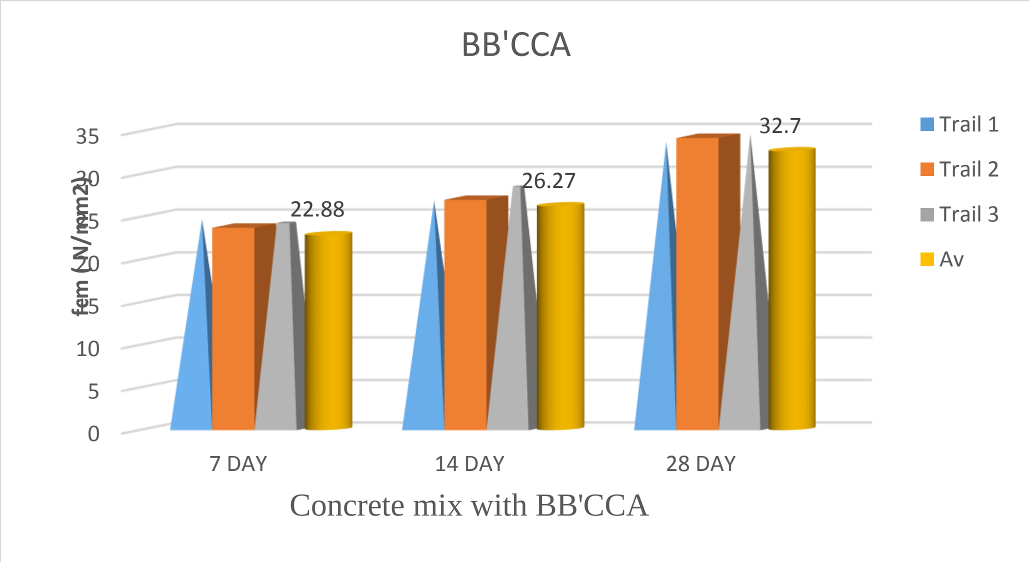

Figure 37:Concrete mix with BB’CCA

Figure 37 shows the development of compressive strength of concrete mixes with crushed coarse aggregate, under different types of curing environments for up to 28 days. The maximum 28-day strength of water cured specimen of about 32.7 MPa was achieved for mix BB'CCA that contained all ranges of particles.the reasons for gaining medium range compressive strength as compared with other quarry is that the engineering properties of this particular quarry exhibit better/ medium quality material.

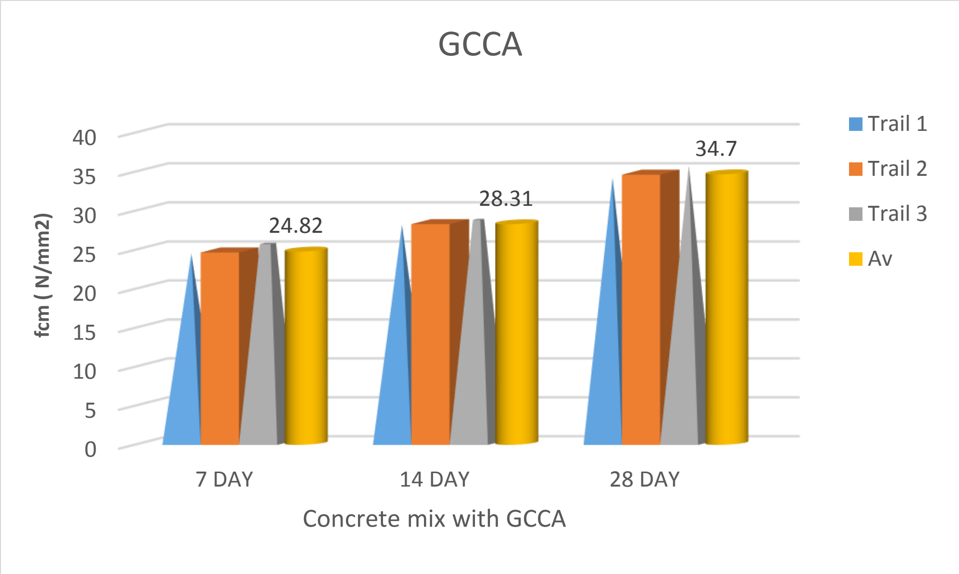

Figure 38:Concrete mix with GCCA

Figure 38 shows the development of compressive strength of concrete mixes with crushed coarse aggregate, under different types of curing environments for up to 28 days. The maximum 28-day strength of water cured specimen of about 32.7 MPa was achieved for mix GCCA that contained all ranges of particles.

Despite having almost similar properties of the aggregates and variable strength parameters, GCCA Concrete showed higher compressive strengths.This shows that this quarry has regular size aggregates with uniform gradations. Whereas other quarries like, SCCA, and KCCA have shown acceptable compressive strength. From results, it was observed that the KCCA have a very low compressive strength due to poor quality Crushed aggregates. It was noticed that the strength of concrete was mainly dependent of the type of aggregates. It is very important to investigate the geological characteristics of quarries including rocks and their aggregates.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Conclusion for Aggregates Quality Evaluation

Coarse aggregate samples were carefully collected from crusher sites. To evaluate those aggregates basic geometrical and physical tests were performed in a laboratory as per Ethiopia, American and British standards among five quarry crushed coarse aggregates (Beda Buna, Shenteradion, Kisho, Buna Board and Geruke) and one fine aggregate (gambela sand). From the evaluation, it is observed that there is some variation in the properties of the aggregates.

From all crushed coarse aggregate samples collected from five quarry sites crushers, two of coarse aggregate samples did not satisfy the grading envelope on sieve size 25mm.

Evaluation of specific gravity values of commonly used aggregates with ASTM and BS has shown that specific gravity of commonly used aggregates fulfills the specifications. Among them, kisho coarse aggregate exhibited the lowest value of water absorption which was 0.78%. Similarly, a maximum value of water absorption was obtained with Buna board coarse aggregate which was 1.17%. Aggregate Impact value (AIV) and Aggregate Crushing value (ACV) of coarse aggregates play the major role in the development of resistance in hardened concrete against impact and compressive loads, respectively. The aggregate impact value gives a relative measure of the resistance of an aggregate to sudden shock or impact. The standard specifications laid down by ASTM, and BS normal aggregate impact value should be less or equal to 30% and 30% respectively. The aggregate crushing value gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load. Aggregates having lower crushing value are preferred. ASTM and BS specify that when aggregate crushing value shall not exceed 30% and 30% of aggregate used in concrete. Greater is the ACV; more is the strength of concrete. The results of this study concerning AIV and ACV of aggregates obtained from four quarry site crushed aggregate which is commonly used aggregates in Jimma University construction indicate that those aggregates confident to be used in concrete with confidence. Out of five quarry crushed coarse aggregates, the lowest value of AIV was yielded by Kisho aggregate, and the highest was yielded by Buna board aggregate. Hence, from impact value and crushed value, all quarry site crushed coarse aggregates are suitable for building construction.

Flaky particles should be avoided as much as possible. ASTM specification limits for flakiness index is 35% max, BS 812-105.1 is 40 max. From the experimental observations of flakiness index, it is found that the flakiness index of crushed stones coarse aggregates are within the permissible limit of the standards with the maximum of 24% and hence, they are suitable for building construction purposes.

Specific gravity is the measure of quality and strength of the material. The allowable range limits of a specific gravity of aggregates in ACI is from 2.3-2.9, so from the experimental tests, the results are between 2.769 and 2.9 , So all crushed coarse aggregate samples commonly used in Jimma Town are suitable for concrete works.

Water absorption of an aggregate is usually accepted as a measure of its porosity. Water absorption affects the water-cement ratio and the workability of concrete. The usual allowable limit for water absorption is 4% maximum for normal concrete. Among the five coarse aggregate samples, sample three aggregate exhibited the lowest value of water absorption which was 0.78%. Similarly, a maximum value of water absorption was obtained with sample four aggregate which was 50% greater than the water absorption of sample three.

The test value of Sodium sulfate soundness ranges from 2.2 to 2.9% (while the acceptable is <12% for concrete aggregate). Therefore all samples are chemically sound and resistance against chemical weathering. In other words, all samples of coarse aggregate tested in laboratory passed the soundness tests.

The results of physical and geometrical tests on aggregates obtained from beda buna, shenteradion, kisho, buna board and geruke crushers indicate that those aggregates used with confidence to make concrete of required properties.

For fine aggregates, different construction standards were used such are ES, ASTM and BS standards for evaluation of their suitability as building concrete material. Starting with, the fineness modulus is a ready index of coarseness and fineness of the material, ASTM range lies between 2.15 to 3.38 for ES 2.0-3 for BS 1.15-4.01. From experimental tests, the results show that the gradation of those sand samples was in between the maximum and the minimum limit of ASTM, BS, and ES. Therefore, fineness modulus perspective the sand samples were satisfied all standard specifications.

The ACI suggests the approximate bulk density of aggregate commonly used in normal-weight concrete for both compact and loose ranges from about 1280 to 1920 kg/m3. The laboratory tests for unit weight was done for both compact and loose thus the result showed, figuratively, for both compact and loose thus the result showed 1498 kg/m3 and 1394.2 kg/m3 for Gambela sand, so the sand sample is within the specification, so the sand sample is confident on unit weight.

ASTM specification limits the amount of material passing the 75 µm (No. 200) sieve to 5% in fine aggregate. Laboratory test evaluation showed that Gambela sand samples satisfied ASTM and ES limitation and it is suggested for building construction.

The results of overall aggregate properties pointed out that all crushed aggregates are within the international and local specification limits and it is suitable for use in concrete.

5.2 RECOMMENDATION

Recommendation for Aggregates Quality Evaluation

- Kisho and shteradion crushed coarse aggregates must be blend before using in concrete works.
- Due to an evaluation of geometrical and physical properties of coarse and fine aggregates, Geruke quarry crushed coarse aggregate beda buna and buna board quarry crushed aggregates are recommendable concrete aggregates for the best quality building constructions.
- The fact that this study determined that Geruke Crushed Coarse Aggregates are qualified the engineering characteristics tests and recommended for the best quality of concreting works in Jimma Town .
- Aggregate must be fit for the purpose to which they are used . hence , they need to be produced to acceptable quality standards.
- Crushed coarse aggregates must be washed before using for the construction purposes to remove impurities.

REFERENCES

[1] Abebe Dinku (June 2002), Addis Ababa University Institute of Technology, Construction Materials Laboratory Manual, Faculty of Technology, Department of Civil Engineering, Construction Technology and Management.

[2] ACI Committee E-701 (2007), ACI Education Bulletin E1-07, Aggregate for Concrete, American Concrete Institute.

[3] Chair of construction management (2011), Student handout on Performance Management in construction.

[4] Chung, W. H. editor (1999) Understanding Quality Assurance in Construction A practical guide to ISO 9000 for contractors, Taylor and Francis Group, LLC.

[5] Duggal, K. S. (2008), BUILDING MATERIALS, (3RD revised ed.), New age international (p) limited, publishers.

Duncan, R W. (1996), Project Management Body Of Knowledge, Project Management Institute, 39-93

[6] Ethiopian standards ES C. D3. 201, "Aggregates, Normal Concrete Aggregates," 1990.

[7] Garold, D. O. (2000), Project management for engineering and construction. The McGran-Hill Companies, 185-239

[8] Kosmatka, H. S., Kerkhoff, B., Panarese, C. W. (2003), Design and Control of Concrete Mixtures, (14th ed.), Portland Cement Association, 21-105.

[9] Lamond, F. J., Pielert, H. J. Editors (1994), Significance of Tests and Properties of Concrete and Concrete-Making Materials STP 169D, ASTM International, 1-435

[10] Mengesha, W. J., Eshetu, A. (July 2005), *Student handout on Principle of Construction Management.*

[11] Merritt, F. S., Ricketts, J. T. chief editors (2001), *Building Design and Construction Handbook*, (6ndEd.), McGraw-Hill.

[12] Nawy, G. E. Editor-in-Chief (2008), Concrete Construction Engineering Handbook, (2ND ed.), Taylor & Francis Group, LLC, 1-1 – 1-26.

[13] Neville, A.M and Brook, J.J, (2010); Concrete Technology, Pearson Education Limited, 1-76.

[14] Newell, W. M. (2005), Preparing for the Project Management Professional (PMP) Certification Exam, (3RD ED.), American Management Association, 47-103.

[15] Ralph, L. K., Irwin S. L. (1998), Project Management Practitioner's Handbook. AMACOM Books, 122-140.

[42] Rumane, R. A. (2011), Quality Management in Construction Projects, Taylor and Francis Group, LLC, 121-33.

[16] Savitha, R., Ranatunge, N.B.M., A Study on Types and Quality of Aggregates Used in Building Construction

APPENDIX: A Standards And Specification Of Aggregates And Concrete

Standards and specification of aggregate and concrete

Table 1: Properties of concrete influenced by aggregate properties

Relevant aggregate property	Standard test	Typical values	Comments
Concrete property—Durability: Resistance to freezing and thawing			
Sulfate soundness	ASTM C 88 Text reference(2.1.1)	Fine agg - 1 to 10% Coarse agg - 1 to 12%	`Magnesium sulfate ($MgSO_4$) gives higher loss percentages than sodium sulfate ($NaSO_4$); test results have not been found to relate well to aggregate performance in concrete.
Resistance to freezing and thawing	ASTM C 666 and CRD-C-114 -Performance of aggregate in air-entrained concrete by rapid cycles Text reference(2.1.1)	Durability factor of 10 to 100%	Normally only performed for coarse aggregate since fine aggregate does not affect concrete freezing and thawing to any large extent; results depend on moisture conditioning of coarse aggregates and concrete.
	ASTM C 682 – Aggregate in concrete, dilation test with slow freeze	Period of frost immunity from 1 to more than 16 weeks	Results depend on moisture conditioning of Aggregate and concrete. For specimens that do not reach critical dilation in the test period, no specific value can be assigned.
	AASHTO T 103 - Test of unconfined aggregate in freeze-thaw		Used by some U.S. Departments of Tran potation; test is not highly standardiz Between agencies. Results may help judge Quality of aggregate in regional area.
Absorption	ASTM C 127 – Coarse aggregate Text reference(2.1.1)	0.2 to 4%	Typical values are for natural aggregates. Most blast-furnace slag coarse aggregates are between 4 and 6%, fine aggregate about one percent less.
	ASTM C 128 - Fine aggregate Text reference(2.1.1)	0.2 to 2%	Some researchers have found a general trend of reduced durability for natural coarse aggregate in concrete exposed to freezing and thawing with increased absorption.
Porosity	None	1 to 10% by volume for coarse	Porosity - The ratio, usually expressed as a percentage, of the volume of voids in a

	Text reference(2.1.1)	aggregate	material to the total volume of the material, including the voids.
Pore structure	None Text reference(2.1.1)		Mercury intrusion methods and gas or vapor absorption techniques can be used to estimate pore size distribution and internal sur face area of pore spaces.
Permeability	None Text reference(2.11)	—	Permeability of aggregate materials to air or water is related to pore structure.
Texture and structure and lithology	ASTM C 295 - Petrographic examination	Quantitative report of rock type and minerals present	Estimation of the resistance of the aggregate to freezing damage; type of particles that may produce popouts or disintegration
Presence of clay and fines	ASTM C 117 - Amount by washing Text reference(3.70)	Fine agg - 0.2 to 6% Coarse agg - 0.2 to 1%	Larger amounts of material finer than the 75µm sieve can be tolerated if free of clay min erals. Does not include clay balls.`
Resistance to degradation	ASTM C 131 and C 535 Text reference(2.1.4)	15 to 50% loss	These tests impart a good deal on impact to the aggregate as well as abrasion; therefore, results not directly related to abrasion test of concrete.
	C 1137		Degradation of fine aggregate
Abrasion resistance	ASTM C 418 - Sand blasting Text reference(2.1.4)	Volume of concrete removed per unit area	These tests are performed on concrete samples containing the aggregate(s) under investigation and may provide the user with a more direct answer.
Durability index	ASTM D 3744	Separate values are obtained for fine and coarse aggregate ranging from 0 to 100	This test was developed in California and indicates resistance to the production of clay-like fines when agitated in the presence of water.
Concrete property—Durability: Alkali-aggregate reactivity			
Aggregate reactivity	ASTM C 295 - Petrographic examination Text reference(2.1.5)	Presence and amount of potentially reactive minerals	For important engineering works. Tests for potential expansion due to aggregate reactivity in moist exposure are often conducted using the cement-aggregate combinations expected on the project.
	ASTM C 227 - Mortar bar expansion	0.01 to 0.20% or more after 6	Both fine and coarse aggregate can be tested. Coarse aggregates must be crushed

	Text reference(2.1.5.1)	months	to fine aggregate sizes.

	ASTM C 289 - Chemical method Text reference(2.1.5.1)	Values are plotted on a graph	Degree of risk from alkali-aggregate reactivity is surmised from the position of the points on the graph. Many slowly reacting aggregates pass this test.
	ASTM C 586 - Rock cylinder method Text reference(2.1.5.3)	0.01 to 0.20% or more after 6 months	Used for preliminary screening of potential for alkali-carbonate reactivity.
Concrete property—Durability: Resistance to heating and cooling			
Coefficient of thermal expansion	CRD-C-125 - Aggregate particles Text reference(2.1.3)	1.0 to 9.0 x 10^{-6}/F	Normally not a problem for concrete. FHWA has developed a procedure for concrete.
Concrete property—Strength			
Tensile strength	ASTM D 2936 - Rock cores Text reference(2.2)	300-2300 psi	Strength tests are not normally run on aggregates, per se.
Compressive strength	ASTM D 2938 - Rock cores	10,000-40,000 psi	
Organic impurities	ASTM C 40 Text reference(4.5)	Color Plate No. 3 or less	Color in sodium hydroxide (NaOH) solution.
	ASTM C 87	85 to 105%	Strength comparison with sand washed to remove organics.
Particle shape	ASTM C 295 - Petrographic Text reference(4.5)	Appearance of particles	A variety of particle shape tests are available. None are widely used as specific values.
	ASTM D 4791 - Coarse aggregate Text reference(5.1)	% flat or elongated	
	CRD-C-120 - Fine aggregate	% flat or elongated	
	ASTM D 3398	Particle shape index	More angular particle produces a higher index value.
Concrete property—Volume change			
Grading and fineness modulus	ASTM C 136 Text reference(4.2)	Grading	

Modulus of elasticity	None Text reference(2.3, 2.1.2, and 2.1.3)	1.0-10.0 x 10^6 psi	
Presence of fines	ASTM C 117	See above	Presence of clay and other fines can increase drying shrinkage.
Presence of clay	ASTM D 2419	70 to 100%	
Maximum size	ASTM C 136	1/2 to 6 in	
Grading	ASTM C 136	See ASTM C 33	Grading can affect paste concrete.

Sources: ACI 221R-96 ;(2001) Guide for Use of Normal Weight and Heavyweight Aggregates in Concrete Reported by ACI Committee 221: PP -221R-3 Table 1.1 —Properties of concrete influenced by aggregate properties

APPENDIX: B Concrete Test

1 CONCRETE TEST

1.1 Mix Design Procedure Used In This Research as Per ACI 211.1

The mix design for C-25 non air entrained normal strength concrete is done as per ACI 211.1. The data from test results, which are important for mix design are:

Table 3.2.1The data from test results

Properties of coarse aggregate	`BBCA	SCCA	KCCA	BB'CCA	GCCA
Maximum size (mm) =	20	20	20		
Unit weight (kg/m3)	1539	1562.	1580	1527	1573
Specific gravity =	2.805	2.828	2.855	2.807	2.855
Absorption (%) =	0.96	0.87	0.82	1.17	0.78
Free moisture content (%) =	1	1	1	1	1
Loose unit weight (Kg/m3) =					
Properties of fine aggregate					
Unit weight (kg/m3)	1324				
Fineness modulus =	2.42				
Specific gravity =	2.63				
Absorption (%) =	1.97				
Free moisture content (%) =	1				
Loose unit weight (Kg/m3)					
Specific gr. Of Cement (O.P.C) =	3.15				

Step 1: Slump (ACI 211.1-91 Table 6.3.1 Appendix C)

Table 3.2.2 - Recommended slumps for various types of construction

Concrete construction	Slump, mm (in.)	
	Maximum*	Minimum
Reinforced foundation walls and footings	75 (3)	25 (1)
Plain footings, caissons, and substructure walls	75 (3)	25 (1)
Beams and reinforced walls	100 (4)	25 (1)
Building columns	**100 (4)**	**25 (1)**
Pavements and slabs	75 (3)	25 (1)
Mass concrete	75 (3)	25 (1)

Sources: ACI 211-1-91 pp-211.1-7 Table 6.3.1

Slump, mm (in.) =**25 (1) -100 (4)** (minimum slump possible) is selected. For the three mix design

Step 2: Maximum size of aggregate

Maximum size is fixed to be 20 mm.

Step 3: Target mean strength calculation

Table 5.3.2.2 pp-68 Required Average Compressive Strength When Data Are Not Available to Establish a Standard Deviation Adapted from ACI 318M.

fcr =25+8.5=33.5MPa

Table 3.2.3: Required Average Compressive Strength When Data Are Not Available To Establish a Sample Standard Deviation

Specified compressive strength, f' c, Mpa	Required average compressive strength, f'cr, MPa	Adapted from ACI 318.
Less than 21	f' c + 7.0	**f'cr,= f' c + 8.5**
21 to 35	f' c + 8.5	f'cr, =25+8.5=33.5MPa
Over 35	1.10 f' c + 5.0	

Sources: ACI-318M; Table 5.3.2.2 pp-68

Step 4: W/C ratio

For 30MPa W/C ratio is 0.54 and for 35MPa W/C ratio is 0.47. The W/C ratio can be found by interpolation as follows:

$$\frac{W}{C} = \frac{(0.54-0.47)}{(30-35)} * (33.5 - 30) + 0.54$$

Table 3.2.4: Relationship between water cement or water-cementitious materials ratio and compressive strength of concrete

Compressive Strength at 28 days, MPa	Water-cementitious materials ratio by mass
	Non-air-entrained Concrete
45	0.38
40	0.42
35	0.47
30	0.54
25	0.61
20	0.69
15	0.79

Source: ACI 211.1-91; Table A1.5.3.4 (a) PP- 211 .1-22

Step 5: Mixing water amount

For maximum size of aggregate of 20mm, slump 25 to 50mm (minimum range) and non-air entrained concrete the mixing water requirement according to ACI table below

Mixing water amount = 190 Kg/M^3

Table; 3.2.5: approximate mixing water and air content requirements for different slumps and nominal maximum sizes of aggregates (SI)

Water, Kg/m3 of concrete for indicated nominal maximum sizes of aggregate								
Slump, (mm)	Aggregate size(mm)							
	9.5	12.5	19.0	25	37.5	50	75	150
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	
Approximate amount of entrapped air in non-air-entrained concrete, percent	3	2.5	2	1.5	1	0.5	0.3	0.2

Source: ACI 211.1-91; Table; a1.5.3.3 PP- 211 .1-22

Step 6: Cement Amount

Cement content = Mixing water amount/ W/C ratio

190/0.49=**387** Kg/m^3

Step 7: coarse aggregate amount

For maximum size aggregate =20mm and sand fineness modulus of 2.42 the dry bulk volume can be interpolated between fineness modulus of 2.4 and 2.6 that is

$$\begin{matrix} 2.40 & 2.42 & 2.60 \\ 0.66 & X & 0.64 \end{matrix} \quad X = \frac{(0.66-0.64)}{(2.40-2.60)}(2.42-2.40)+0.66$$

$$= 0.658 \sim \mathbf{0.66}$$

Table 3.2.6: Volume of coarse aggregate per unit of volume of concrete

Nominal maximum size of aggregate, in.	Volume of oven-dry-rodded coarse aggregate* per unit volume of concrete for different fineness moduli of fine aggregate			
`	2.4	2.6	2.8	3
(⅜ in.)	0.5	0.48	0.46	0.44
(½ in.)	0.59	0.57	0.55	0.53
(¾in.)	0.66	0.64	0.62	0.6
1	0.71	0.69	0.67	0.65
(1½ in.)	0.75	0.73	0.71	0.69
2	0.78	0.76	0.74	0.72
3	0.82	0.8	0.78	0.76
6	0.87	0.85	0.83	0.81

Sources: (ACI 211.1-91 Table 6.3.6 pp. - 211.1-12)

Step 7.1 (unit weight for Beda Buna quarry site is 1539.67)

Step 7.1 for BBCCA(1539.67)

Coarse aggregate amount = 0.646***1539.67**=994.63 kg/m3 But **1539.67** kg/m3 is air dry bulk unit weight, and it has to be adjusted to air dry condition and back to SSD by dividing by total moisture and multiplying by absorption respectively. i.e.

Coarse aggregate $=\frac{W_{SSD}}{TM} * \text{Absorption} = [\frac{994.63}{(1+(\frac{0.61}{100})}*(1+\frac{0.959}{100})]$ = **998.1 kg/m^3**

Step 7.2 for unit weight for Sheteradion quarry site is 1562.06)

Coarse aggregate amount = 0.646*1562.06=1009.1 kg/m3 But 1562.06 kg/m3 is air dry bulk unit weight, and it has to be adjusted to air dry condition and back to SSD by dividing by total moisture and multiplying by absorption respectively. i.e.

Coarse aggregate $=\frac{W_{SSD}}{TM} * \text{Absorption} = [\frac{1009.1}{(1+(\frac{0.55}{100})}*(1+\frac{0.865}{100})]$ = **1012.26 kg/m^3**

Step 7.3 for unit weight for Kisho quarry site is 1580.77)

Coarse aggregate amount = 0.646***1580.77**=1021.18 kg/m3 But **1580.77** kg/m3 is air dry bulk unit weight, and it has to be adjusted to air dry condition and back to SSD by dividing by total moisture and multiplying by absorption respectively. i.e.

Coarse aggregate $=\frac{W_{SSD}}{TM} * \text{Absorption} = [\frac{1021.18}{(1+(\frac{0.52}{100})}*(1+\frac{0.820}{100})]$ = **1024.23 kg/m^3**

Step 7.4 for buna board (unit weight for buna board quarry site is 1527.79)

Coarse aggregate amount = 0.646***1527.79**=986.95kg/m3 But **1527.79**kg/m3 is air dry bulk unit weight, and it has to be adjusted to air dry condition and back to SSD by dividing by total moisture and multiplying by absorption respectively. i.e.

Coarse aggregate $=\frac{W_{SSD}}{TM} * \text{Absorption} = [\frac{986.95}{(1+(\frac{0.74}{100})}*(1+\frac{1.17}{100})]$ = **991.16 kg/m^3**

Step 7.5 Geruke (unit weight for Geruke quarry site is 1573.08**)**

Coarse aggregate amount = 0.646*1573.08=1016.209 kg/m3 But 1573.08 kg/m3 is air dry bulk unit weight and it has to be adjusted to air dry condition and back to SSD by dividing by total moisture and multiplying by absorption respectively. i.e.

Coarse aggregate $=\frac{W_{SSD}}{TM} * \text{Absorption} = [\frac{1016.209}{(1+(\frac{0.498}{100})}(1+\frac{0.7833}{100})]$ = **1014.22 kg/m^3**

Step 8: Fine aggregate amount

Step 8.1 for Beda Buna quarry site

Fine aggregate amount = 2.595[1000-(180+$\frac{360}{3.15}$+$\frac{998.1}{2.805}$+50] = **778.20 kg/m^3**

Step 8.2 for Sheteradion quarry site

Fine aggregate amount = 2.595[1000-(180+$\frac{360}{3.15}$+$\frac{1012.26}{2.828}$+50] = **772.72 kg/m^3**

Step 8.3 for Kisho quarry site

Fine aggregate amount = 2.595[1000-(180+$\frac{360}{3.15}$+$\frac{1024.23}{2.855}$+50] = **770.62 kg/m^3**

Step 8.4 for buna board quarry site

Fine aggregate amount = 2.595[1000-(180+$\frac{360}{3.15}$+$\frac{991.16}{2.807}$+50] = **785.28 kg/m^3**

Step 8.5 for Geruke quarry site

Fine aggregate amount = 2.595[1000-(180+$\frac{360}{3.15}$+$\frac{1014.23}{2.855}$+50] = **779.71 kg/m^3**

Step 9: Moisture correction

Ingredients	Estimated quantity(Kg)	Absorption (%)	Absorbed water(Kg)	Natural moisture (%)	N.M.C (Kg)	Adjusted quantity (Kg)
Moisture correction for BBCCA Mix design						
Water	180	_	_	_	_	182
Cement	360	_	_	_	_	360
C. Aggregate	998.1	0.959	12.58	1.00	9.981	1000.7
Air content	_	_		_	_	_
F. Aggregate	778.20	1.94	15.56	1	7.782	785.98
Total	2316.3					2328.68
Moisture correction for SCCA Mix design						
Water	180	_	_	_	_	174.57
Cement	360	_	_	_	_	360
C. Aggregate	1012.25	0.865	12.51	1.00	10.12	1014.64
Air content	_	_		_	_	_
F. Aggregate	772.72	1.94	15.45	1	7.72	780.45
Total	2324.97					2329.66
Moisture correction for KCCA Mix design						
Water	180	_	_	_	_	174.56
Cement	360	_	_	_	_	360
C. Aggregate	1024.23	0.820	12.5	1.00	10.24	1026.49
Air content	_	_		_	_	_
F. Aggregate	770.62	1.94	15.4	1	7.70	778.32

Total	2334.85					2339.37
Moisture correction for BB'CCA Mix design						
Water	180					175.24
Cement	360					360
C. Aggregate	991.16	1.17	13	1.00	9.91	994.25
Air content				_		
F. Aggregate	785.28	1.94	15.7	1	7.85	793.13
Total	2316					2323
Moisture correction for GCCA Mix design						
Water	180					174.2
Cement	360					360
C. Aggregate	1011.14	0.78	12.1	1.00	10.11	1013.13
Air content				_		
F. Aggregate	779.71	1.94	15.58	1	7.79	787.50
Total	2331					2335

1.2 MECHANICAL PROPERTIES OF HARDENED CONCRETE CUBE COMPRESSION STRENGTH RESULTS

Sample No=#1(BBCCA)
Concrete Class: C-25
Source of Coarse Agg.: @Jimma
Source Of Sand: Gambella Sand

	VE STRENGTH OF CONCRETE									
	days									
	Descriptions	7 Day`s *Cube* Strength			14 Day`s *Cube* Strength			28 Day`s *Cube* Strength		
1	Cubes Number	$7D_1$	$7D_2$	$7D_3$	$14D_1$	$14D_2$	$14D_3$	$28D_1$	$28D_2$	$28D_3$
2	Aggregate, kg/m3	1000.7								
3	Sand ,kg/m^3	785.98								
4	Cement, kg/m^3	360								
5	Water, kg/m^3	182								
6	Slump, mm	48			48			48		
7	Weight of Cube, gm.	7963.24	7974.0	7979	7906.9	7910.7	8009.3	8032.8	7968.7	8007.1
8	Volume of Cube,cm^3	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
9	Density of Cube g/cm^3									
10	Failing Load, KN	529.425	549	523.35	638.1	624.15	569.7	745.87	781.2	754.42
11	Cross-sectional Area ,mm^2	0.0225			0.0225			0.0225		
12	Compressive Strength, N/mm^2	23.53	24.40	23.26	28.36	27.74	25.32	33.15	34.72	33.53
13	Average Compressive Strength, N/mm^2	23.73			27.14			33.8		

Sample No=#1(SCCA)
Concrete Class: C-25
Source of Coarse Agg.: @Jimma
Source Of Sand: Gambella Sand

VE STRENGTH OF CONCRETE

days

	Descriptions	7 Day`s *Cube* Strength			14 Day`s *Cube* Strength			28 Day`s *Cube* Strength		
1	Cubes Number	$7D_1$	$7D_2$	$7D_3$	$14D_1$	$14D_2$	$14D_3$	$28D_1$	$28D_2$	$28D_3$
2	Aggregate, kg/m3	1014								
3	Sand ,kg/m^3	780								
4	Cement, kg/m^3	360								
5	Water, kg/m^3	175								
6	Slump, mm	47			47			47		
7	Weight of Cube, gm.	7963.24	7974.0	7979	7906.9	7910.7	8009.3	8032.8	7968.7	8007.1
8	Volume of Cube,cm^3	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
9	Density of Cube g/cm^3									
10	Failing Load, KN	424.35	481.50	479.25	548.10	494.1	552.15	678.37	651.83	667.80
11	Cross-sectional Area ,mm^2	0.0225			0.0225			0.0225		
12	Compressive Strength, N/mm^2	18.86	21.40	21.30	24.36	21.96	24.54	30.15	28.97	29.68
13	Average Compressive Strength, N/mm^2	20.52			23.62			29.60		

Sample No=#1(KCCA)
Concrete Class: C-25
Source of Coarse Agg.: @Jimma
Source Of Sand: Gambella Sand

VE STRENGTH OF CONCRETE

days

	Descripti ons	7 Day`s *Cube* Strength			14 Day`s *Cube* Strength			28 Day`s *Cube* Strength		
1	Cubes Number	$7D_1$	$7D_2$	$7D_3$	$14D_1$	$14D_2$	$14D_3$	$28D_1$	$28D_2$	$28D_3$
2	Aggregat e, kg/m3	1026								
3	Sand ,kg/m^3	778								
4	Cement, kg/m^3	360								
5	Water, kg/m^3	174								
6	Slump, mm	46			46			46		
7	Weight of Cube, gm.	7963.24	7974.0	7979	7906.9	7910.7	8009.3	8032.8	7968.7	8007.1
8	Volume of Cube,cm^3	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
9	Density of Cube g/cm^3									
10	Failing Load, KN	394.65	457.2	459	465.3	520.87	530.55	656.33	649.8	604.13
11	Cross-sectional Area ,mm^2	0.0225			0.0225			0.0225		
12	Compressive Strength, N/mm^2	17.54	20.32	20.4	20.68	23.15	23.58	29.17	28.88	26.85
13	Average Compressive Strength, N/mm^2	19.42			22.47			28.30		

Sample No=#1(BB'CCA)
Concrete Class: C-25
Source of Coarse Agg.: @Jimma
Source Of Sand: Gambella Sand

VE STRENGTH OF CONCRETE

days

	Descriptions	7 Day`s *Cube* Strength			14 Day`s *Cube* Strength			28 Day`s *Cube* Strength		
1	Cubes Number	$7D_1$	$7D_2$	$7D_3$	$14D_1$	$14D_2$	$14D_3$	$28D_1$	$28D_2$	$28D_3$
2	Aggregate, kg/m3	994								
3	Sand ,kg/m^3	793								
4	Cement, kg/m^3	360								
5	Water, kg/m^3	175								
6	Slump, mm	50			50			50		
7	Weight of Cube, gm.	7963.24	7974.0	7979	7906.9	7910.7	8009.3	8032.8	7968.7	8007.1
8	Volume of Cube,cm^3	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
9	Density of Cube g/cm^3									
10	Failing Load, KN	518.63	492.53	533.03	580.5	607.05	585.67	760.05	768.37	678.37
11	Cross-sectional Area ,mm^2	0.0225			0.0225			0.0225		
12	Compressive Strength, N/mm^2	23.05	21.89	23.69	25.8	26.98	26.03	33.78	34.15	30.17
13	Average Compressive Strength, N/mm^2	22.88			26.27			32.7		

Sample No=#1(GCCA)
Concrete Class: C-25
Source of Coarse Agg.: @Jimma
Source Of Sand: Gambella Sand

VE STRENGTH OF CONCRETE

days

	Descriptions	7 Day`s *Cube* Strength			14 Day`s *Cube* Strength			28 Day`s *Cube* Strength		
1	Cubes Number	$7D_1$	$7D_2$	$7D_3$	$14D_1$	$14D_2$	$14D_3$	$28D_1$	$28D_2$	$28D_3$
2	Aggregate, kg/m3	1013								
3	Sand ,kg/m^3	787								
4	Cement, kg/m^3	360								
5	Water, kg/m^3	174								
6	Slump, mm	51			51			51		
7	Weight of Cube, gm.	7963.24	7974.0	7979	7906.9	7910.7	8009.3	8032.8	7968.7	8007.1
8	Volume of Cube,cm^3	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375	0.003375
9	Density of Cube g/cm^3									
10	Failing Load, KN	544.95	555.97	574.43	629.55	637.43	643.95	764.1	779.85	798.3
11	Cross-sectional Area ,mm^2	0.0225			0.0225			0.0225		
12	Compressive Strength, N/mm^2	24.22	24.71	25.53	27.98	28.33	28.62	33.96	34.66	35.48
13	Average Compressive Strength, N/mm^2	24.82			28.31			34.7		

APPENDIX:C1 Fine Aggregate Result Table

Gambela sand Gradation

Sieve size (mm)	Mass retained in Kg	Cum. Mass retained in Kg	% retained	Cum. % retained	% passing	ES	
						Min.	Max.
12.5	0	0	0	0	100	100	100
9.5	0	0	0	0	100	100	100
4.75	0.0208	0.0208	4.16	4.16	95.84	95	100
2.36	0.0272	0.048	5.44	9.6	90.4	80	100
1.18	0.0644	0.1124	12.88	22.48	77.52	50	85
0.6	0.09905	0.21145	19.81	42.29	57.71	25	60
0.3	0.1795	0.39095	35.9	78.19	21.81	10	30
0.15	0.0931	0.48405	18.62	96.81	3.19	2	10
FM	**2.54**		**SUM**	**253.53**			
TOTAL Mass	**0.48**						

UNIT WEIGHT

Compact Unit Weight

	Trail 1	Trail 2	Trail 3
Weight of sand + container (gm):-	3861.02gm	3861.12gm	3860.89gm
Weight of container (gm):-	865gm	865gm	865gm
Weight of sand (gm):-	2996.02gm	2996.12gm	2995.89gm
Volume of container (cm³):-	2000 cm3	2000 cm3	2000 cm3
Unit weight of sand (gm):-	1.498gm/cc	1.498gm/cc	1.4979gm/cc
		Average unit weight = 1.498gm/cc	
		Average unit weight = 1,498kg/m³	

Loose Unit Weight

	Trail 1	Trail 2	Trail 3
Weight of sand + container:-	3653.31gm	3653.22gm	3653.71gm
Weight of container:-	865gm	865gm	865gm

Weight of sand :-	2788.31gm	2788.22gm	2788.71gm
Volume of container:-	2000cm3	2000cm3	2000cm3
Unit weight of sand:-	1.394155gm/cc	1.39411gm/cc	1.394355gm/cc
		Average unit weight = 1.3942gm/cc	
		Average unit weight = 1,394.2kg/m³	

SPECIFIC GRAVITY

The mass of the fine aggregate sample is determined in SSD, oven dry and submerged states.

These values are then used to calculate bulk specific gravity, bulk SSD specific gravity, apparent specific gravity, and absorption.

Relative density (specific gravity) is computed from the equation

Bulk Relative Gravity=$\frac{A}{B+C-D}$ Bulk Relative Gravity (SSD) =$\frac{B}{B+C-D}$

A = is the mass of the oven-dry sample in air

B = is the mass of the SSD sample in air

C = is the mass of the jar or flask filled with water; and.

D= is the mass of the jar or flask with specimen and water to the Calibration or filling mark

		unit	Trial 1	Trial 2	Average(Mean)
Mass of saturated surface-dry specimen	A	gm	500	505	
Mass of pyknometer + specimen + water	B	gm	1860.81	1869.48	
Mass of pyknometer filled with water	C	gm	1553.83	1558.71	
Mass of oven-dry specimen	D	gm	490.63	495.24	
Specific gravity on an oven -dry basis			2.542	2.550	2.546
Specific gravity on a SSD basis			2.590	2.600	2.595
Apparent specific gravity			2.672	2.685	2.678
Water Absorption		%	1.910	1.971	1.940

Materials Finer Than 75-µm in Mineral Aggregates by Washing

(1) Before washing.

Mass of Container	Wa	425gm
Mass of Container + Dry Sample	Wb	1425gm
Mass of Dry Sample	W1 = Wb - Wa	1000gm

(2) After washing.

Mass of Container	Wc	425gm
Mass of Container + Dry Sample	Wd	1400.9gm
Mass of Dry Sample	W2 = Wd - Wc	975.9gm

Material Finer than 75-μm

$(W_1 - W_2) / W_1 \times 100\% =$ 2.41 %

APPENDIX C2: Coarse Aggregate Result Tables

GRADATION
BEDA BUNA QUARRY SITE CRUSHED STONE

Sieve size (mm)	Mass retained in Kg	Cum. Mass retained in Kg	% retained	Cum. % retained	% passing	ASTM Standard	
						Min.	Max.
37.5	0	0	0	0	100	100	100
25	0.436	0.436	10.9	10.9	89.1	90	100
19.5	1.6756	2.1116	41.89	52.79	47.21	40	85
12.5	1.0376	3.1492	25.94	78.73	21.27	10	40
9.5	0.696	3.8452	17.4	96.13	3.87	0	15
4.75	0.1152	3.9604	2.88	99.01	0.99	0	5
TOTAL KG	3.9604						

SPECIFIC GRAVITY

The bulk specific gravity and bulk specific gravity SSD are calculated as follows;

Bulk Specific Gravity = $\frac{A}{B-C}$

Where

A = mass of oven-dry sample in air;

Bulk Specific Gravity (SSD) = $\frac{B}{B-C}$

B = mass of saturated surface-dry mass in air; and

Apparent Specific Gravity = $\frac{A}{A-C}$

Where

W = mass of the original sample, and

W_{OD} = mass of the dried sample.

Absorption, %, = $\frac{W_{SSD}-W_{OD}}{w_{OD}} * 100$

Test	Formula	1	2	**AVG.**
Wt Oven-dry Sample	A (gm)	3982.171	3980.3	
Wt of saturated surface dry sample in air	B (gm)	4020.241	4018.58	
Wt of sample in water	C (gm)	2589.55	2583.37	
Absorption	(B-A)×100/A	0.956	0.961	**0.959**
Apparent Bulk Specific gravity	A/(A-C)	2.86	2.850	**2.855**
Bulk Specific gravity/Dry basis	A/(B-C)	2.783	2.773	**2.778**

Bulk Specific gravity/SSD basis	B/(B-C)	2.81	2.80	**2.805**

UNIT WEIGHT

Compact Unit Weight

	Trail 1	Trail 2	Trail 3
Weight of sand + container (gm):-	17101.45	17101.62	17101.99
Weight of container (gm):-	1705	1705	1705
Weight of sand (gm):-	15396.45	15396.62	15396.99
Volume of container (cm³):-	10000	10000	10000
Unit weight of sand (gm/cm³):-	1.539645	1.539662	1.539699
Average Unit weight of sand (gm/cm³):-		1.539668667	
Average Unit weight of sand (kg/m³):-		1,539.67	

Loose Unit Weight

	Trail 1	Trail 2	Trail 3
Weight of sand + container (gm):-	15916.98	15916.78	15916.65
Weight of container (gm):-	1705	1705	1705
Weight of sand (gm):-	14211.98	14211.78	14211.65
Volume of container (cm³):-	10000	10000	10000
Unit weight of sand (gm/cm³):-	1.421198	1.421178	1.421165
Average Unit weight of sand (gm/cm³):-		1.421180333	
Average Unit weight of sand (kg/m³):-		1,421.18	

FLAKINESS INDEX

Sieve Size (mm)		Mass Retained (gm)	**Mass Passing (gm)**
100% Passing	**100% Retained**		
37.5	**28**	1568.476	543.5
28	**20**	7501.1072	1354.23
20	**14**	3940.1496	878.14
14	**10**	3573.0228	692.37
10	**6.3**	-----	-------
Total	**----**	**16582.7556**	**3468.24**

		FI=Total Mass Passing / Total Mass Retained * 100
FI=	**21%**	

AGGREGATE CRUSHED VALUE

The ACV is computed from the equation

Aggregate Crushing Value (ACV) =$(\frac{M2}{M1}) * 100$

M1 (gm.) = Mass of aggregate before test, passing 14.0mm and retain 10.0mm sieves

M2 (gm.) = Mass of aggregate after compression, Passing 2.36mm sieves

Test No.		1	2
Mass of aggregate before test, passing 14.0mm and retain 10.0mm sieves	M1 (g)	2719.39	2707.25
Mass of aggregate after compression, Passing 2.36mm sieves	M2 (g)	484.595	434.51
ACV(%) = (M2/M1)*100		17.82	16.05
Average ACV(%) = (Test1 + Test2)/ 2		**16.585**	

AGGREGATE IMPACT VALUE

$$AIV=\frac{M2}{M1}*100$$

Where M1 is the mass of oven-dried test specimen (in g) and M2 is the mass of oven dried material passing the 2.35 mm test sieve (in g)

Test No.		1	2
Mass of aggregate before test, passing 14.0mm and retain 10.0mm sieves	M1 (g)	735.48	721.81
Mass of aggregate after compression, Passing 2.36mm sieves	M2 (g)	110.396	107.694
ACV(%) = (M2/M1)*100		15.01	14.92
Average ACV(%) = (Test1 + Test2)/ 2		**14.965**	

SOUNDNESS USING SODUIM SULFATE

Sieve Size(mm)		Grading of original sample (%)	Mass of Test Fraction(gm)		% Passing Sieve used to Determine Loss	Weighted Average (Corrected % Loss)
Passing	Retained		Before	After		
63.5	37.5	----	----			

37.5	19.5	53.92	1534	1517	1.1	0.60
19.5	9.5	35.43	1008	985	2.3	0.81
9.5	4.75	10.65	303	268	11.6	1.23
Total		100	2845	2770		2.6
		Soundness Loss	**2.6%**			

SHETERADION QUARRY SITE CRUSHED STONE

GRADATION

Sieve size (mm)	Mass retained in Kg	Cum. Mass retained in Kg	% retained	Cum. % retained	% passing	ASTM Standard	
						Min.	Max.
37.5	0	0	0	0	100	100	100
25	0.3048	0.3048	7.62	7.62	92.38	90	100
19	1.4852	1.79	37.13	44.75	55.25	40	85
12.5	1.4748	3.2648	36.87	81.62	18.38	10	40
9.5	0.33	3.5948	8.25	89.87	10.13	0	15
4.75	0.37	3.9648	9.25	99.12	0.88	0	5
TOTAL KG	3.9648						

SPECIFIC GRAVITY

Test #	Formula	1	2	AVG.
Wt Oven-dry Sample	A (gm)	3986.481	3984.9	
Wt of SSD sample in air	B (gm)	4023.392	4020.0	
Wt of sample in water	C (gm)	2599.182	2597.0	
Absorption	(B-A)×100/A	0.85	0.880	0.865
Apparent Bulk Specific gravity	A/(A-C)	2.87	2.870	2.870
Bulk Specific gravity/Dry basis	A/(B-C)	2.8	2.800	2.800
Bulk Specific gravity/SSD basis	B/(B-C)	2.825	2.830	2.828

UNIT WEIGHT

Compact Unit Weight

	Trail 1	Trail 2	Trail 3
Weight of sand + container (gm):-	17325.44	17325.69	17325.54
Weight of container (gm):-	1705	1705	1705
Weight of sand (gm):-	15620.44	15620.69	15620.54
Volume of container (cm³):-	10000	10000	10000
Unit weight of sand (gm/cm³):-	1.562044	1.562069	1.562054
Average Unit weight of sand (gm/cm³):-	1.562055667		
Average Unit weight of sand (kg/m³):-	1,562.056		

Loose Unit Weight

	Trail 1	Trail 2	Trail 3
Weight of sand + container (gm):-	16186.98	16186.78	16186.65
Weight of container (gm):-	1705	1705	1705
Weight of sand (gm):-	14481.98	14481.78	14481.65
Volume of container (cm³):-	10000	10000	10000
Unit weight of sand (gm/cm³):-	1.448198	1.448178	1.448165
Average Unit weight of sand (gm/cm³):-	1.448180333		
Average Unit weight of sand (kg/m³):-	1,448.18		

FLEKINESS INDEX

Sieve Size (mm)		Mass Retained (gm)	**Mass Passing (gm)**
100% Passing	**100% Retained**		
37.5	**28**	805.9746	378.42
28	**20**	5211.615	742.58
20	**14**	4445.4744	619.17

14	**10**	1452.6132	398.93
10	**6.3**	1362.3228	351.68
Total	**----**	**13278**	**2490.78**
		FI=Total Mass Passing / Total Mass Retained * 100	
FI=	**19%**		

AGGREGATE CRUSHED VALUE

The ACV is computed from the equation

Aggregate Crushing Value (ACV) =$(\frac{M2}{M1}) * 100$

M1 (gm.) = Mass of aggregate before test, passing 14.0mm and retain 10.0mm sieves

M2 (gm.) = Mass of aggregate after compression, Passing 2.36mm sieves

Test No.		1	2
Mass of aggregate before test, passing 14.0mm and retain 10.0mm sieves	M1 (g)	2593.4	2598.7
Mass of aggregate after compression, Passing 2.36mm sieves	M2 (g)	386.16	413.97
ACV(%) = (M2/M1)*100		14.89	15.93
Average ACV(%) = (Test1 + Test2)/ 2		**15.41**	

AGGREGATE IMPACT VALUE

$$AIV=\frac{M2}{M1}*100$$

Where M1 is the mass of oven-dried test specimen (in g) and M2 is the mass of oven dried material passing the 2.35 mm test sieve (in g)

Test No.		1	2
Mass of aggregate before test, passing 14.0mm and retain 10.0mm sieves	M1 (g)	675.73	681.51
Mass of aggregate after compression, Passing 2.36mm sieves	M2 (g)	94.467	96.5
ACV(%) = (M2/M1)*100		13.98	14.16
Average ACV(%) = (Test1 + Test2)/ 2		**14.07**	

SOUNDNESS USING SODIUM SULFATE

Sieve Size(mm)		Grading of original sample(%)	Mass of Test Fraction(gm)		% Passing Sieve used to Determine Loss	Weighted Average (Corrected % Loss)
Passing	Retained		Before	After		
63.5	37.5	----	----			
37.5	19.5	53.84	1521	1504	1.1	0.60
19.5	9.5	35.50	1003	981	2.2	0.78
9.5	4.75	10.65	301	271	10.0	1.06
Total		100	2825	2756		2.4
		Soundness Loss	**2.4%**			

KISHO QUARRY SITE CRUSHED STONE

GRADATION

Sieve size (mm)	Mass retained in Kg	Cum. Mass retained in Kg	% retained	Cum. % retained	% passing	ASTM Standard	
						Min.	Max.
37.5	0	0	0	0	100	100	100
25	0.396	0.396	9.9	9.9	90.1	90	100
19	1.772	2.168	44.3	54.2	45.8	40	85
12.5	1.0	3.168	25	79.2	20.8	10	40
9.5	0.5332	3.7012	13.33	92.53	7.47	0	15
4.75	0.2596	3.9608	6.49	99.02	0.98	0	5
TOTAL KG	3.9608						

SPECIFIC GRAVITY

	Formula	1	2	**AVG.**
Wt Oven-dry Sample	A (gm)	3993.0126	3990.96	
Wt of saturated surface dry sample in air	B (gm)	4025.356	4024.1	
Wt of sample in water	C (gm)	2617.889	2612.1	
Absorption	(B-A)×100/A	0.81	0.830	**0.820**
Apparent Bulk Specific gravity	A/(A-C)	2.9	2.890	**2.895**

Bulk Specific gravity/Dry basis	A/(B-C)	2.837	2.830	**2.834**
Bulk Specific gravity/SSD basis	B/(B-C)	2.86	2.850	**2.855**

UNIT WEIGHT

Compact Unit Weight

	Trail 1	Trail 2	Trail 3
Weight of sand + container (gm):-	17512.78	17512.68	17512.71
Weight of container (gm):-	1705	1705	1705
Weight of sand (gm):-	15807.78	15807.68	15807.71
Volume of container(cm³):-	10000	10000	10000
Unit weight of sand (gm/cm³):-	1.580778	1.580768	1.580771
Average Unit weight of sand (gm/cm³):-	1.580772333		
Average Unit weight of sand (kg/m³):-	1,580.77		

Loose Unit Weight

	Trail 1	Trail 2	Trail 3
Weight of sand + container (gm):-	16313.62	16313.35	16313.51
Weight of container (gm):-	1705	1705	1705
Weight of sand (gm):-	14608.62	14608.35	14608.51
Volume of container (cm³):-	10000	10000	10000
Unit weight of sand (gm/cm³):-	1.460862	1.460835	1.460851
Average Unit weight of sand (gm/cm³):-	1.460849333		
Average Unit weight of sand (kg/m³):-	1,460.85		

FLEKINESS INDEX

Sieve Size (mm)		Mass Retained (gm)	**Mass Passing (gm)**
100% Passing	**100% Retained**		
37.5	**26.5**	937.9878	232.12
28	**19**	6424.2246	803.67
20	**13.2**	3350.9685	572.43
14	**9.5**	2424.3159	479.98

10	**6.7**	1031.5032	305.76
Total	**----**	**14169**	**2393.96**
		FI=Total Mass Passing / Total Mass Retained * 100	
FI=	**17%**		

AGGREGATE CRUSHED VALUE

The ACV is computed from the equation

Aggregate Crushing Value (ACV) $=(\frac{M2}{M1}) * 100$

M1 (gm.) = Mass of aggregate before test, passing 14.0mm and retain 10.0mm sieves

M2 (gm.) = Mass of aggregate after compression, Passing 2.36mm sieves

Test No.		*1*	*2*
Mass of aggregate before test, passing 14.0mm and retain 10.0mm sieves	*M1 (g)*	2580.51	2589.11
Mass of aggregate after compression, Passing 2.36mm sieves	*M2 (g)*	377.01	408.56
ACV(%) = (M2/M1)*100		14.61	15.78
Average ACV(%) = (Test1 + Test2)/ 2		**15.195**	

AGGREGATE IMPACT VALUE

$$AIV=\frac{M2}{M1}*100$$

Where M1 is the mass of oven-dried test specimen (in g) and M2 is the mass of oven dried material passing the 2.35 mm test sieve (in g)

Test No.		*1*	*2*
Mass of aggregate before test, passing 14.0mm and retain 10.0mm sieves	*M1 (g)*	593.19	581.66
Mass of aggregate after compression, Passing 2.36mm sieves	*M2 (g)*	84.41	77.59
ACV(%) = (M2/M1)*100		14.23	13.34
Average ACV(%) = (Test1 + Test2)/ 2		**13.785**	

SOUNDNESS USING SODIUM SULFATE

Sieve Size(mm)		Grading of original sample (%)	Mass of Test Fraction(gm)		% Passing Sieve used to Determine Loss	Weighted Average (Corrected % Loss)
Passing	Retained		Before	After		

63.5	37.5	----	----			
37.5	19.5	53.49	1501	1489	0.8	0.43
19.5	9.5	35.71	1002	983	1.9	0.68
9.5	4.75	10.80	303	271	10.6	1.14
Total		100	2806	2743		2.2
		Soundness Loss	**2.2%**			

BUNA BOARD QUARRY SITE CRUSHED STONE

GRADATION

Sieve size (mm)	Mass retained in Kg	Cum. Mass retained in Kg	% retained	Cum. % retained	% passing	ASTM Standard	
						Min.	Max.
37.5	0	0	0	0	100	100	100
25	0.5004	0.5004	12.51	12.51	87.49	90	100
19	1.7588	2.2592	43.97	56.48	43.52	40	85
12.5	0.8896	3.1488	22.24	78.72	21.28	10	40
9.5	0.578	3.7268	14.45	93.17	6.83	0	15
4.75	0.2424	3.9692	6.06	99.23	0.77	0	5
TOTAL KG	3.9692						

SPECIFIC GRAVITY

	Formula	1	3	**AVG.**
Wt Oven-dry Sample	A (gm)	3975.648	3978.81	
Wt of saturated surface dry sample in air	B (gm)	4024.55	4022.97	
Wt of sample in water	C (gm)	2588.75	2591.3	
Absorption	(B-A)×100/A	1.23	1.11	**1.170**
Apparent Bulk Specific gravity	A/(A-C)	2.867	2.8676	**2.867**
Bulk Specific gravity/Dry basis	A/(B-C)	2.77	2.780	**2.775**
Bulk Specific gravity/SSD basis	B/(B-C)	2.803	2.810	**2.807**

UNIT WEIGHT

Compact Unit Weight

	Trail 1	Trail 2	Trail 3
Weight of sand + container (gm):-	16982.83	16982.94	16982.88
Weight of container (gm):-	1705	1705	1705
Weight of sand (gm):-	15277.83	15277.94	15277.88
Volume of container (cm³):-	10000	10000	10000
Unit weight of sand (gm/cm³):-	1.527783	1.527794	1.527788
Average Unit weight of sand (gm/cm³):-	1.527788333		
Average Unit weight of sand (kg/m³):-	1,527.79		

Loose Unit Weight

	Trail 1	Trail 2	Trail 3
Weight of sand + container (gm):-	15805.98	15805.08	15804.64
Weight of container (gm):-	1705	1705	1705
Weight of sand (gm):-	14100.98	14100.08	14099.64
Volume of container (cm³):-	10000	10000	10000
Unit weight of sand (gm/cm³):-	1.410098	1.410008	1.409964
Average Unit weight of sand (gm/cm³):-	1.410023333		
Average Unit weight of sand (kg/m³):-	1,410.02		

FLEKINESS INDEX

Sieve Size (mm)		Mass Retained (gm)	**Mass Passing (gm)**
100% Passing	**100% Retained**		
37.5	**26.5**	1431.0375	447.32
28	**19**	8916.7485	1423.47
20	**13.2**	3953.3565	972.08
14	**9.5**	3172.287	979.81
10	**6.7**	991.5705	618.66
Total	**----**	**18465**	**4441.34**

		FI=Total Mass Passing / Total Mass Retained * 100	
FI=	**24%**		

AGGREGATE CRUSHED VALUE

The ACV is computed from the equation

Aggregate Crushing Value (ACV) =$(\frac{M2}{M1}) * 100$

M1 (gm.) = Mass of aggregate before test, passing 14.0mm and retain 10.0mm sieves

M2 (gm.) = Mass of aggregate after compression, Passing 2.36mm sieves

Test No.		1	2
Mass of aggregate before test, passing 14.0mm and retain 10.0mm sieves	M1 (g)	2621.02	2614.48
Mass of aggregate after compression, Passing 2.36mm sieves	M2 (g)	536.0	485.77
ACV(%) = (M2/M1)*100		20.45	18.58
Average ACV(%) = (Test1 + Test2)/ 2		**19.515**	

AGGREGATE IMPACT VALUE

$$AIV=\frac{M2}{M1}*100$$

Where M1 is the mass of oven-dried test specimen (in g) and M2 is the mass of oven dried material passing the 2.35 mm test sieve (in g)

Test No.		1	2
Mass of aggregate before test, passing 14.0mm and retain 10.0mm sieves	M1 (g)	841.02	830.56
Mass of aggregate after compression, Passing 2.36mm sieves	M2 (g)	143.9	139.202
ACV(%) = (M2/M1)*100		17.11	16.76
Average ACV(%) = (Test1 + Test2)/ 2		**16.935**	

SOUNDNESS USING SODIUM SULFATE

Sieve Size(mm)		Grading of original sample (%)	Mass of Test Fraction(gm)		% Passing Sieve used to Determine Loss	Weighted Average (Corrected % Loss)
Passing	Retained		Before	After		
63.5	37.5	----	----			

37.5	19.5	53.52	1511	1490	1.4	0.74
19.5	9.5	35.67	1007	981	2.6	0.92
9.5	4.75	10.80	305	271	11.1	1.20
Total		100	2823	2742		2.9
		Soundness Loss	**2.9%**			

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APPENDIX: D Aggregate quality test picture