Jimma University

School of Graduate Studies

Jimma Institute of Technology

Faculty of Civil and Environmental Engineering

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Construction Engineering and Management Stream

EFFECTS OF MACHINE CRUSHED ANIMAL BONES AS PARTIAL REPLACEMENT OF COARSE AGGREGATES IN CONCRETE

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: Blen Demissie

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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

EFFECTS OF MACHINE CRUSHED ANIMAL BONES AS PARTIAL REPLACEMENT OF COARSE AGGREGATES IN CONCRETE

By

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ABSTRACT

The demand of natural coarse aggregates in the construction industry has been increased while at the same time the generated wastes from different areas are increasing substantially. Various researches aiming to produce concrete from manufactured or aggregates from industrial or agricultural by-products, is gradually becoming very popular. This is due to the fact that industrial and agricultural wastes are being re-used thereby ensuring the environmental degradation arising from the production of these waste products is curtailed to the barest minimum. It is very essential to protect the natural coarse aggregates for further generation. To fulfill the demand of such naturally occurring materials, various substitutes are used.

In the present study, an attempt has made on the suitability of the machine crushed animal bones as partial or full replacement for crushed coarse aggregates in concrete works. The study has been carried out at 10%, 25%, 50%, 75%, and 100% replacement levels of crushed coarse aggregate(CCA) by crushed animal bone (CAB) aggregate by weight and a comparative study has been done between normal concrete and crushed animal bone (CAB) concrete.

To achieve the objectives of this study aggregate test were carried out in accordance with the appropriate ASTM standards. Physical and mechanical properties of machine crushed animal bones and locally available crushed coarse aggregate have been determined and compared. An auxiliary test like compression was also made on cubes for C-25 grade concrete and curing for 7days and 28 days.

The result showed that both the crushed coarse aggregate and crushed animal bone aggregate were within the acceptable limit of ASTM C-33 and ASTM C-330 standards. And the Compressive strength tests showed that approximately 10% of the crushed animal bones in replacement for crushed coarse aggregate were quite satisfactory with no compromise in compressive strength.

***Keywords**: crushed animal bone, concrete, light weight aggregate, compressive strength, unit weight.*

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ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
$\beta cc(t)$	Age function for strength
BS	British Standard
CCA	Crushed Coarse Aggregate
CAB	Crushed animal bone
ES	Ethiopian Standard
f_{ck} ,cube	mean concrete cube compressive strength
f_{cu}	specified characteristic cube compressive strength
FM	Fineness Modulus
KN	Kilo Newton
LWC	light-weight concrete
NWC	normal-weight concrete
N.M.C	Natural Moisture Content
ODOT	Ohio Department of Transportation
OPC	Ordinary Portland Cement
PCC	Portland Cement Concrete
PKS	Palm Kernel Shell
PKSC.	Palm Kernel Shell Concrete
PSD	Particle Size Distribution
S	coefficient for cement type used with the age function
SPR	Simplified Practice Recommendation
SSD	Saturated Surface-Dry
WisDOT	Wisconsin Department of Transportation
W_{OD}	Weight of Oven Dry

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 [1]. 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. In a normal concrete, 75 to 85% of the volume of concrete is aggregate that makes the cost of concrete relatively low [4].

The demand of natural coarse aggregates in the construction industry has been increased. It is very essential to protect the natural coarse aggregates for further generation. To fulfill the demand of such naturally occurring materials, various substitutes are used. But now days it is very difficult problem for available of coarse and fine aggregates. So researchers developed waste management strategies to apply for replacement of these aggregates for specific need. These Natural resources are depleting worldwide while at the same time the generated wastes from different areas are increasing substantially [6]. The sustainable development for construction involves the use of nonconventional and innovative materials, and recycling of waste materials in order to compensate the lack of natural resources and to find alternative ways conserving the environment. Animal bones are one of the materials that are considered as a waste material which could have some partial usage in construction industry as partial substitute of either fine or coarse aggregates. In the present era there are lot of animals which are used as meat food like cows, goats, sheep and etc. Some of these waste bones are just thrown in garbage bins and pits causing uncleanness to the environment .Therefore is a need to look into how can the bones can be utilized beneficially in making concrete that can offer good quality constructions. There are lot wastes from these industries cause environmental pollution. In this world wide they are thousand tons of animal waste bones are produced every year. So there is small scope we can use these animal bones are used in construction industry.

A lot of work has been carried out to improve the properties of concrete by using various materials. As far as bone is concerned, it is a very light and hard material composed of a cellular component and an extracellular matrix. Besides being light and hard, bone does not deteriorate easily. The remains of animal (bones) are dug out even after hundreds of years. Archeological Survey of India (ASI) providing a vital clue that the decaying period of bones is good enough to be used in concrete works [3].In addition to this an effort has been made to utilize these bones (crushed) to study the effect of animal bones on concrete. Some references made aggregate crushing value tests on bones and they have given good results for making better quality concrete [6].

1.2 Statement of the Problem

Natural resources are depleting worldwide while at the same time the generated wastes from different areas are increasing substantially. The demand of natural coarse aggregates in the construction industry has been increased. It is very essential to protect the natural coarse aggregates for further generation. Various researches aiming to produce concrete from manufactured or aggregates from industrial or agricultural by-products, is gradually becoming very popular. This is due to the fact that industrial and agricultural wastes are being re-used thereby ensuring the environmental degradation arising from the production of these waste products is curtailed to the barest minimum [3].

Animal bones are one of the non decaying waste products of abattoir houses in Ethiopia, polluting the environment and causing problems on the life of human beings and animals, which are not still controlled yet. Some of these waste bones are just thrown in garbage bins and pits causing uncleanness to the environment. The recent land sliding accident causing the death of 115 people in Addis Ababa near waste dumping area the so called “koshe” can be an example to the problem. In addition to this the demand of coarse aggregates in the fast growing construction industry has been increased in the country. It is very essential to protect the normal coarse aggregates from further degradation by decreasing the time and cost of aggregates for bringing them from the very far quarry sites.

The problem of these abattoir house wastes are also a problem in Jimma town in which the wastes are dumped everywhere in the surrounding but not decayed rather causing environmental pollution and different health problems. Therefore it is a need to look into how the bones can be utilized beneficially in making concrete that can offer good quality constructions.

1.3 Research Questions

The research questions that this study ought to answer are as follows:

1. What are the engineering properties and characteristics of crushed animal bone (CAB) aggregates?
2. What are the effects of crushed animal bone aggregates on the fresh and hardened concrete?
3. How much is the optimum amount of percent replacement of crushed animal bone with a maximum compressive strength?

1.4 Objectives

1.4.1 General objective

- The main objective of study is to investigate the effects of machine crushed animal bones as partial replacement of coarse aggregates in C-25 concrete.

1.4.2 Specific Objectives

1. To determine the engineering properties and characteristics of crushed animal bone aggregates.
2. To determine the effect of crushed animal bone aggregates on the fresh and hardened concrete.
3. To determine the optimum amount of percent replacement of crushed animal bone to crushed coarse aggregate with a maximum compressive strength.

1.5 Scope of Study

The focus of the research was to look into how waste animal bones can be utilized beneficially in making concrete that can offer good quality constructions. And to investigate the effects of machine crushed animal bones as partial to full replacement of coarse aggregates in concrete by determining the engineering properties and characteristics of crushed animal bone aggregates and to check the optimum percent replacement of CAB aggregate in concrete with a maximum compressive strength.

1.6 Significance of the Study

This study investigates the effects of machine crushed animal bone aggregates as partial replacement of locally available crushed coarse aggregate in concrete and it checks optimum percent replacement with the maximum compressive strength of concrete using

(CAB) aggregate around Jimma zone providing helpful information to various stake holders such as,

The society will be benefit from the environmental conservation that clean and safe environments will be created and a need for construction materials, results in environmental degradation, will be minimized. The City Administration of Jimma town will be benefited from the study as a source of information for the construction industry that can help to reduce waste and supply an alternative construction material regarding to standard and specifications and the Owners, contractors and consultants will be benefited from the study as a source of information for the fastest growing building construction projects and high rise constructions in the country, and also in case of Jimma city.

CHAPTER TWO

LITERATURE REVIEW

Concrete is a heterogeneous mixture of cement, water, fine aggregates, and coarse aggregates. Many studies have indicated that coarse aggregates normally constitute about 75 percent of the volume of concrete and therefore have a major influence on the properties of concrete. The strength and durability of concrete is one such property that is mainly controlled by the type and amount of coarse aggregate. In the next section some characteristics of Crushed animal bone aggregate and crushed coarse aggregates are described along with a detailed explanation and its effects on concrete. The roles of physical, mechanical, and chemical properties of Crushed animal bone aggregate and crushed coarse aggregates on the behaviour and performance of portland cement concrete are often described in terms of their effects on concrete strength.

2.1 Concrete Constituent Materials

In a concrete mixture the aggregates which are generally graded in size from fine to pebbles or crushed stones, form the inert mineral filler material which the cement paste binds together. These aggregates generally occupy 65 to 75 percent of the volume of concrete [11]. Aggregates were first considered to simply be filler for concrete to reduce the amount of cement required. However, it is now known that the type of aggregate used for concrete can have considerable effects on the plastic and hardened state properties of concrete [12].

Aggregates can be broadly classified into four different categories: these are heavyweight, normal weight, lightweight and ultra-lightweight aggregates. However in most concrete practices only normal weight and lightweight aggregates are used [13]. In a Portland cement concrete mix, coarse and fine aggregates typically make up 60 to 70% of the total volume. For this reason, aggregate characteristics, such as size, shape, and surface texture influence greatly the properties of a concrete mix [2].

a. Coarse Aggregate

Coarse aggregate generally occupies about 30 to 40% of the volume of concrete and is therefore expected to influence the performance of concrete significantly [14]. Coarse aggregate may be available in several different size groups, such as 19 to 4.75 mm (3/4 to No. 4), or 37.5 to 19 mm (1-1/2 to 3/4 in.). ASTM C 33, "Standard Specifications for

Concrete Aggregates," lists several such size groups using the Simplified Practice Recommendation (SPR) number designation. The number and size of sieves selected for a sieve analysis is dependent upon the particle sizes present in the sample and the grading requirements specified [15].

Table 2.1 Sieves commonly used for concrete aggregate sieve analysis

Standard sieve designation		Nominal sieve opening	
		Mm	in.
Coarse sieves			
75 mm	(3in.)	75	3
63 mm	(21/2 in.)	63	2.5
50 mm	(2 in.)	50	2
37.5mm	(11/2in.)	37.5	1.5
25.0mm	(1 in.)	25.0	1
19.0mm	(3/4 in.)	19.0	0.75
12.5 mm	(1/2 in.)	12.5	0.5
9.5 mm	(3/8 in.)	9.5	0.375
Fine sieves			
4.75 mm	(No. 4)	4.75	0.1870
2.36 mm	(No. 8)	2.36	0.0937
1.18 mm	(No. 16)	1.18	0.0469
600 µm	(No. 30)	0.60	0.0234
300 µm	(No. 50)	0.30	0.0117
150 µm	(No. 100)	0.15	0.0059
75 µm	(No. 200)	0.075	0.0029
Pan		*1000 µm = 1 mm.	

Sources: ACI Education Bulletin E1-99; Table 1 Aggregates for Concrete E1 3

b. Fine Aggregates

Sand is one of the normal natural fine aggregates used in concrete production. Failure of concrete structures leading to collapse of buildings has initiated various researches on the quality of construction materials. Information on the effect of silt and clay content and organic impurities present in building sand being supplied in Nairobi Country as well as their effect to the compressive strength of concrete was lacking [17]. That portion of an aggregate passing the 4.75 mm (No. 4) sieve and predominantly retained on the 75 mm

(No. 200) sieve is called fine aggregate or sand [16]. Sands and gravels are defined on the basis of particle size rather than composition. Sand and gravel deposits are accumulations of the more durable rock fragments and mineral grains, which have been derived from the weathering and erosion of hard rock mainly by glacial and river action, but also by wind [18].

c. Cement

Ordinary Portland (Type-I) cement is suitable for general concrete construction when there is no exposure to sulphates in the soil. The standard requires that it is made from 95 to 100 percent of Portland cement clinker and 0 to 5 percent of minor additional constituents. Minor additional constituents are one or more of the other cementious materials or filler. Filler is defined as any natural or inorganic mineral material other than a cementious material [14].

The cements are manufactured to produce the proper amount of expansion without adversely affecting the concrete quality and retaining the normal range of concrete shrinkage [14]. Cement is one of the most expensive components of concrete. Although cement paste is required to fill aggregate voids, bind them together and provide mobility to fresh concrete, it is also responsible for drying shrinkage, heat generation and porosity [19].

Nowadays, after several important technical improvements, concrete made with Portland cement is probably the most used manmade material in the world. In a concrete mixture the function of the cement is to react with the water forming a plastic mass when the concrete is fresh and a solid mass when the concrete is hard [21].

d. Water

The function of the water, other than enabling the chemical reactions that cause setting and hardening to proceed, is to lubricate the mixture of aggregates and cement in order to facilitate placing. Some standards stipulate that water fit for drinking is generally suitable for making concrete [12]. Water quality is the most consistent of the constituents of concrete but water quantity, as it affects the free/water cement ratio, is most important for control of consistence, strength and durability. Almost any natural water that is drinkable (potable) and has no pronounced taste or odour is satisfactory as mixing water for making concrete. Excessive impurities in mixing water may affect not only setting time, concrete strength, and volume stability (length change), but may also cause efflorescence or corrosion of reinforcement. Where possible, water with high concentrations of dissolved solids should be avoided. ASTM C1602M allows the use of potable water without testing and includes methods for qualifying non potable sources of water with consideration of effects on setting time and strength. Testing frequencies are established to ensure continued monitoring of water quality [21].

2.2 Aggregate for Concrete

Aggregate ; Granular material, such as sand, gravel, crushed stone, and iron blast-furnace slag, used with a cementing medium to form a hydraulic cement concrete or mortar [21].

Concrete, Normal Weight; Concrete containing only aggregate that conforms to ASTM C33.

Concrete aggregates shall conform to one of the following specifications:

(a) Normal weight: ASTM C33;

(b) Lightweight: ASTM C330.

2.2.1 Classification

Aggregates may be broadly classified as natural or artificial, both with respect to source and method of preparation. Natural sands and gravels are the product of weathering and the action of wind or water, while stone sands and crushed stone are produced by crushing natural stone. Aggregates may be produced from igneous, sedimentary, or metamorphic rocks, but the presence or absence of any geological type does not, by itself, make an aggregate suitable or unsuitable for use in concrete. The acceptance of an aggregate for use in concrete on a particular job should be based upon specific information obtained from tests used to measure the aggregate quality, or upon its service record, or both. A typical consensus specification for concrete aggregate, both fine and coarse aggregate, is ASTM C 33 [16].

Natural aggregate deposits, called pit-run gravel, consist of gravel and sand are the product of weathering and the action of wind or water, they can be readily used in concrete after minimal processing. Natural gravel and sand are usually dug or dredged from a pit, river, lake, or seabed. Naturally occurring concrete aggregates are a mixture of rocks and minerals. According to BS 882:1992 Coarse aggregates consist of one or a combination of gravels or crushed stone with particles predominantly larger than 5 mm (3⁄16in.) [18].

1. Bank gravel: naturally deposited gravel intermixed with sand or clay found in and next to rivers and streams. Also known as "Bank run" or "River run".
2. Bench gravel: a bed of gravel located on the side of a valley above the present stream bottom, indicating the former location of the stream bed when it was at a higher level.
3. Lag gravel: a surface accumulation of coarse gravel produced by the removal of finer particles.
4. Pea gravel: gravel that consists of small, rounded stones used in concrete surfaces. Also used for walkways, driveways and as a substrate in home aquariums.
5. Piedmont gravel: Coarse gravel carried down from high places by mountain streams and deposited on relatively flat ground, where the water runs more slowly.

2.2.2 Characteristic of Aggregate

The physical, mechanical and chemical characteristics of aggregates to be studied, a sample should be taken from the larger portion. A sample is a small portion of a larger volume or group of materials such as a stockpile, batch, carload, or truckload about which information is wanted. Sampling is the process of obtaining samples. The properties of the sample are presented as evidence of the properties of the larger unit from which it is taken. A series of samples can be used to provide information about average properties and a pattern of variations in these properties [16].

Samples shall be representative and certain precautions in sampling have to be made. No detailed procedures can be laid down as the conditions and situations involved in taking samples in the field can vary widely from case to case. Nevertheless, a practitioner can obtain reliable results bearing in mind that the sample taken is to be representative of the bulk of the material. The main sample shall be made up of portions drawn from different parts of the whole. The minimum number of these portions is described in A representative sample can be obtained by following the standard procedures detailed in the latest edition of AASHTO T2 and ITM 207, “Method of Sampling Stockpile Aggregate” [23].

Size of Original Samples

The key to any sample program is to obtain a representative sample. A standard sampling method must be followed to obtain uniform samples. The following is a list of recommended minimum sizes of composite samples to be used as a guide when collecting samples (AASHTO T2 and ITM).

Table 2.2 Recommended minimum sizes of collecting samples

Material	Sample Size IB.(Kg)
No. 2 coarse aggregate	220(100)
No. 5 coarse aggregate	110(50)
No. 8 coarse aggregate	55(25)
No. 9 coarse aggregate	35(16)
No. 11 & No. 12 coarse aggregate	25(11)
No. 43 coarse aggregate	110(50)
No. 53 coarse aggregate	135(61)
No. 73 coarse aggregate	80(36)

Source:(AASHTO T2 and ITM).

Figure 2.1: sample Riffling for fine &coarse aggregates to test size

1) **Grading**

The grading is determined in accordance with ASTM C 136, "Sieve or Screen Analysis of Fine and Coarse Aggregates." A sample of the aggregate is shaken through a series of 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. These wire- cloth sieves have square openings. A pan is used to catch material passing the smallest sieve [16].

Maximum aggregate size typically ranges between ¾ and 1.5 in., while about 25 to 45% of the total aggregate content consists of fine aggregate. Special mixes of concrete may require aggregates outside these ranges. Aggregate mixtures can be broadly classified in terms of their particle size distribution (PSD) into three types, as discussed below [16].

Dense-Graded Mixes

Dense-graded aggregate mixes can also be called well-graded, continuous-graded, or straight line-graded mixes. These types of mixes are characterized by an even distribution of particle sizes, such that finer grains can fill the voids between larger ones. Dense-graded mixes have reduced void space leading to increased shear strength, and must be placed in thicker lifts.

a. Open-Graded Mixes

Open-graded mixes, also known as no-fines or harshly-graded mixes contain an even mixture of various coarse particle sizes, but little or no void filling fines. Consequently, they depend heavily on friction between interlocking angular and rough textured coarse fragments for strength. Moreover, the increased void space allows moisture to drain easily, which explains why open-graded aggregates are commonly used in roadway bases.

b. Gap-Graded Mixes

Gap-graded aggregate mixes, also known as skip-graded or armchair-graded, are missing an intermediate size fraction, generally either coarse sand or fine gravel. Leaving a proportion of voids unfilled reduces their compacted density and makes them prone to segregation. Gap-graded mixes can be used either by necessity, as when only coarse aggregate and uniform sand are available, or because rounded dune sand generally improves workability.

Variability in coarse aggregate gradation results from mingling different particle size distributions among concrete batches, and is very common on any construction project. This may be attributed to the aggregate source(s), the stock piling operation, or the method of concrete production. It becomes a costly affair for both the contractor and the producer of the aggregate to ensure a unique and workable gradation of the aggregate, so usually little attention is paid in achieving one [5].

Grading of aggregate is summarised as follows

- For a given volume of coarse aggregate, a larger maximum size reduces the specific surface area of aggregate; and larger aggregate size results in the increases of the perimeter and thickness of interfacial layer between mortar and aggregate so that a larger flaw can be formed and the bond strength decreased [24].
- It affects the workability of concrete which may, in turn, affect the segregation of constituents, bleeding, water-cement requirements, handling, placing, and finishing characteristics. These factors may then affect strength, volume change, durability, and the economy of concrete [26].
- Other research studied shows the effects of using optimized coarse aggregate gradations, which combine practical and economic constraints with attempts to obtain a mix of sizes that will lead to improved workability, durability, and strength [27].
- Unsatisfactory gradation of the aggregates may lead to the following: (a) segregation of the mortar from the coarse aggregates; (b) bleeding of water below and around larger aggregates and on the surface of the concrete; (c) settling of aggregates, leaving paste in the top lift of the concrete; (d) need for chemical admixtures in order to restore workability to the concrete; (e) increased use of cement; (f) insufficient air entrainment and air void distribution; (g) excessive use of water; (h) high porosity of the hardened concrete; (i) high material costs; (j) reduced service life [16].
- Continuously graded aggregates for concrete contain particles ranging in size from the largest to the smallest; in gap-graded aggregates some of the intermediate sizes are absent. Gap-grading may be necessary in order to achieve certain surface finishes [18].
- There are several reasons for specifying both grading limits and maximum aggregate size. Aggregates having a smooth grading curve and neither a deficiency nor excess of any one particle size will generally produce mixtures with fewer voids between particles [16].

2) Particle Shape and Surface Texture

Shape

Aggregate particle shape can usually be classified into one of two types, rounded or angular. Natural aggregates, which are typically found on coastlines or in riverbeds, are typically smooth in texture and round in shape due to weathering. Mechanically ground by machines, crushed aggregates on the other hand are commonly angular in shape and have a rough surface texture. The shape of the aggregate will affect both the strength and workability of concrete [5].

Surface Texture

Surface texture influences chemical inertness, polishing resistance, and, most importantly, bitumen and cement adhesion. Surface textures are typically classified as either rough or smooth, and will influence the tenacity with which the cement paste adheres to the coarse aggregate. Aggregates with a rough surface texture bonded more firmly with cement paste than smooth materials. While these characteristics are important for a quality concrete mixture, it should be noted that good adhesion properties are primarily associated with low strength aggregates [5].Surface texture of the aggregate affects its bond to the cement paste and also influences the water demand of the mix, especially in the case of fine aggregate. The shape and surface texture of aggregate influence considerably the strength of concrete. The effects of shape and texture are particularly significant in the case of high strength concrete [13]. Abroad classification of aggregates on the basis of shape and shape is presented in table 2.3 and 2.4 as given by BS 812: Part 1[18].

Roundness measures the relative sharpness or angularity of the edges and corners of a particle. Roundness is controlled largely by the strength and abrasion resistance of the parent rock and by the amount of wear to which the particle has been subjected. In the case of crushed aggregate, the particle shape depends not only on the nature of the parent rock but also on the type of crusher and its reduction ratio, i.e. the ratio of the size of material fed into the crusher to the size of the finished product. Particles with a high ratio of surface area to volume are also of particular interest for a given workability of the control mix [13].

Elongated and flaky particles are departed from equi-dimensional shape of particles and have a larger surface area and pack in an isotropic manner. Flaky particles affect the durability of concrete, as the particles tend to be oriented in one plane, with bleeding water and air voids forming underneath. The flakiness and elongation tests are useful for general assessment of aggregate but they do not adequately describe the particle shape. The presence of elongated particles in excess of 10 to 15% of the mass of coarse aggregate is generally undesirable, but no recognized limits are laid down [14].

Table 2.3 Particle Shape Classification of Aggregates according to BS 812: Part 1: 1990;

Classification	Description	Examples
Rounded	Fully water-worn or completely shaped	River or seashore gravel;

	by attraction	desert, seashore and wind-blown sand
Irregular	Naturally irregular, or partly shaped by attrition and having rounded edges	Other gravels; land or dug flint
Flaky	Material of which the thickness is small relative to the other two dimensions	Laminated rock
Angular	Possessing well-defined edges formed at the intersection of roughly planar faces	Crushed rocks of all types; talus; crushed slag
Elongated	Material, usually angular, in which the other two dimensions	
Flaky and Elongated	Material having the length considerably larger than the width, and the width considerably larger than the thickness	

Table 2.4 Surface Texture Classification of Aggregates according to BS 812: Part 1: 1990

Group	Surface Texture	Characteristics	Examples
1	Glassy	Conchoidal fracture	Black flint, vitreous slag
2	Smooth	Water-worn, or smooth due to fracture of laminated or fine grained rock	Gravels, chert, slate, marble, some rhyolites
3	Granular	Fracture showing more or less uniform rounded grains	Sandstone, oolite
4	Rough	Rough fracture of fine or medium grained rock containing no easily visible crystalline constituents	Basalt, felsites, porphyry, limestone
5	Crystalline	Containing easily visible Crystalline constituents	Granite, gabbro, gneiss
6	honeycombed	with visible pores and cavities	Brick, pumice, Brick, pumice, expanded clay

3) Bulk Density (Unit Weight)

Bulk density measures the weight of the aggregate that fills a container of unit volume part of which is void because of loose packing of the particles. The bulk density is used to convert quantities by weight to quantities by volume for batching concrete. In general, for comparison of different aggregates and calculation of mix quantities the standard conditions are dry and compact (rodded). However, for scheduling volumetric batch quantities, the unit weight in the loose, damp state should also be known [12].

Figure 2.2 The Cylindrical Metal Measures for the Fine and Coarse Aggregates

In estimating quantities of materials, and in mix computations when batching is done on a volumetric basis, it is necessary to know the conditions under which the aggregate volume is to be measured: (1) loose or compact, and (2) dry, damp, or inundated. The general range in unit weights of some fine and coarse aggregates are shown in Table 2.5.

Table 2.5 General Range in Unit Weight of Some Natural Aggregates

	Material	Kg/m3
1	Sand (dry)	1520 – 1680
2	Gravel	1280 – 1440
3	Crushed Stone	1250 – 1400

Sources: Denamo Addissie 2005; table 2.13

The bulk density (dry-rodded unit weight) of an aggregate is the mass of the aggregate divided by the volume of particles and the voids between particles. Methods for determining bulk density are given in ASTM C 29.

$$\text{Bulk density} = \frac{M_{Agg+cont.} - M_{cont}}{V_{Cont}}$$

The rodded bulk density of aggregates used for normal-weight concrete generally ranges from 1200 to 1760 kg/m3 (75 to 110 lb. /ft3)[13].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. Void contents range from about 30% to 45% for coarse aggregates to about 40% to 50% for fine aggregate. Angularity increases void content while larger sizes of well-graded aggregate and improved grading decreases void content [18].

4) Relative Density (Specific Gravity)

The specific gravity of an aggregate is used in mixture proportioning calculations to find the absolute volume that a given mass of material will occupy in the mixture. Absolute volume of an aggregate refers to the space occupied by the aggregate particles alone; that is the volume of solid matter and internal aggregate pores not including the voids between particles [5].

The bulk specific gravity is defined as the ratio of the weight in air of a given volume of a material at the standard temperature to the weight in air of equal volume of distilled water at the standard temperature. For use in the computation of concrete mixes the bulk specific gravity is always determined for saturated surface dry aggregates. The specific gravities of a number of commonly used aggregates fall within the range of 2.6 to 2.7, although there are satisfactory materials for which the specific gravity falls outside this range [12]. Test methods for finding specific gravity of aggregates are described in ASTM C127, "Specific Gravity and Absorption of Coarse Aggregate, "and ASTM C 128, "Specific Gravity and Absorption of Fine Aggregate" [16].

Four moisture conditions are defined for aggregates depending upon the amount of water held in the pores or on the surface of the particles. These conditions are shown in Figure. 4.1and described as follows:

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

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

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

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

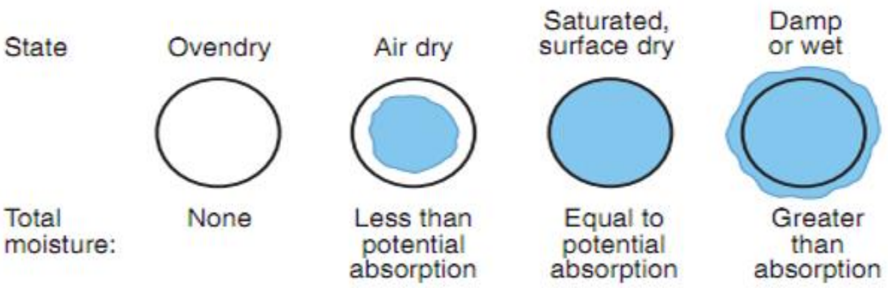

Figure 2.3 Moisture conditions of aggregates [17]

The bulk specific gravity and bulk specific gravity SSD, are calculated as follow (Coarse aggregate)

Bulk specific gravity $=\frac{A}{B-C}$ Bulk specific gravity $_{SSD}=\frac{B}{B-C}$

Where

A = mass of oven-dry sample in air;

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

C = mass of saturated sample

The bulk specific gravity and bulk specific gravity SSD, are calculated as follow (Fine aggregate)

Bulk specific gravity $=\frac{A}{B+C-D}$ Bulk specific gravity $_{SSD}=\frac{B}{B\mp C-D}$

Where

A = mass of oven-dry sample in air;

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

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

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

5) Absorption (moisture contents at SSD)

The various moisture states in which an aggregate may exist have been described previously. Two of these, oven-dry and saturated surface-dry, are used as the basis for specific gravity calculations. However, aggregates stock piled on the job are seldom in either of these states. The aggregates usually carry some free or surface moisture that becomes part of the mixing water. Freshly-washed coarse aggregates **contain free water,** but since they dry quickly, they are sometimes in an air-dry state when used. In this state, they will absorb some of the mixing water when used [16]

Absorption and total moisture content—to calculate the mixing water content of concrete, the absorption of the aggregates and their total moisture content must be known.

- 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 [5].

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

Absorption is a measure of the total pore volume accessible to water and is usually calculated using the results from a specific gravity determination (ASTM C 127 and C 128).

- Total moisture content is measured in accordance with 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.

$$\text{Total Moistre Content, \%,} = \frac{W-W_{OD}}{W_{OD}}*100$$

Where

W = mass of the original sample, and W_{OD} = Mass of the Dried Sample.

- Surface moisture content—Surface or free moisture content of an aggregate can be determined by subtracting the absorption from the total moisture content.

2.3 Effect of Coarse Aggregate Properties on Concrete

Research shows that there is a clear relationship between aggregate characteristics and strength of concrete. Aggregate characteristics have a significant effect on the behavior of fresh and hardened concrete. In fact, flaky, elongated, angular, and unfavorably graded particles lead to higher voids content than, cubical, rounded, and, well-graded particles [19]. Aggregate performance properties have a direct influence on the stability of aggregate particles in the unbound and bound state. An aggregate with a high porosity and low permeability defines the aggregate freezing and thawing critical size whether in the unbound state or the bound state as Portland cement concrete or bituminous concrete [31].The main characteristics of aggregate that affect the performance of fresh and hardened concrete are: Shape and texture, Grading, Absorption, Mineralogy and coatings, Strength and stiffness, Maximum size, Specific gravity or relative density, Soundness and Toughens [19]. Studies by [5] indicated that, mix which consists of natural coarse aggregate is found to be 7% stronger than the corresponding crushed coarse aggregate mix. The natural mixes are stronger than their crushed aggregate counte0rparts by 31% and 26%, respectively. In all three cases, the mixes containing natural coarse aggregate exhibited higher strengths than those with crushed aggregate, contrary to intuitive expectations. Aggregate physical durability properties are typically inter-related. Porosity and absorption are directly related as are absorption and specific gravity. Aggregate that has a high specific gravity generally has a low absorption. These aggregates would generally have a high strength, high abrasion resistance, and a high resistance to dimensional changes. [31]

2.3.1 Grading

Decrease in amount of water improves the compressive strength of concrete. Larger maximum size coarse aggregate with lower water requirement can produce strong concrete. Reduction in water/cement ratio improves the strength of concrete. Using larger aggregate without decrease in amount water decreases the compressive strength. Strength of concrete could also be affected by the type and size of coarse aggregate [18].Particle size and gradation of the aggregate have a significant effect on the behaviour of a concrete mix, affecting its economy, workability, and strength.

Both coarse aggregate and fine aggregate should be uniformly graded. If fine aggregate is too coarse it will produce bleeding, segregation and harshness, but if it is too fine, the demand for water will be increased [16].

Grading or particle size distribution affects significantly some characteristics of concrete like packing density, voids content, and, consequently, workability, segregation, durability and some other characteristics of concrete[19]. One of the physical properties of aggregate that influences the property of concrete is grading of aggregate [15]. Maximum size of aggregate, MSA, influences workability, strength, shrinkage, and permeability. Mixtures with large maximum size of coarse aggregate tend to produce concrete with better workability, probably because of the decrease in specific surface [19].

2.3.2 Surface Texture Particles

Angular and rough surface texture particles granite aggregates may contribute to an increment in compressive strength of up to 20% compared to concrete made with river gravel at the same water/cement ratio [18].Aggregate characteristics of shape, texture, and grading have a significant effect on the performance of fresh Portland cement concrete [31].

2.3.3 Effect of Aggregate Type

The shape of the aggregate will affect both the strength and workability of concrete. Surface texture influences chemical inertness, polishing resistance, and, most importantly, bitumen and cement adhesion. The results conclude that shape and texture play an important role on the performance of fresh concrete, particularly in slump and flow. Results from mixtures with the same grading show that the slump and flow of mixtures increased with the packing density of aggregates and that the super plasticizer dosage required to reach the target slump decreased with the packing density of aggregates. The mean slump varied from 0.16 in. for granite to 2.9 in. for natural aggregate from Indiana [31]. Contrary to expectations, the 28-day compressive strength of natural aggregate mixes was found to be higher than that of the corresponding crushed stone mixes, and this difference was significant, ranging between 16 and 34%. This is probably attributable to the mineralogy of the material [5].

2.3.4 Bulk Density (Unit Weight)

The most appropriate method of assessing the particle density of aggregates in structural concrete is to compare the density against that of typical natural aggregates which is usually about 2.65 kg/m3. The aggregate particle density is an essential property for concrete mix design and also for calculating the volume of concrete produced from a certain mass of materials which is the ratio of mass of a given volume to the mass of same volume of water (BS 812: Part 2 1995).The study showed that the larger the size of the aggregate, the smaller the percentage of cement mortar attached to its surfaces and hence the higher the particle density and the better the aggregate quality [15].

2.3.5 Absorption

The absorption of an aggregate, while not directly related to the quality of the aggregate, can still be used as a preliminary indicator of durability [31]. Aggregate porosity may affect durability as freezing of water in pores in aggregate particles can cause surface pop outs [19].

2.3.6 Effect of Relative Density (Specific Gravity)

Relative density is not necessarily related to aggregate behaviour. However, it has been found that some aggregates compounds of shale, sandstone, and chert that have somewhat low specific gravity may display poor performance, particularly in exposed concrete in northern climates (i.e., low permeability is an indicator of poor durability) [19].

2.4 Specification and Requirements of Aggregate for Normal Weight Concrete

Aggregates, the major constituent of concrete, influence the properties and performance of both freshly mixed and hardened concrete. In addition to serving as an inexpensive filler, they impart certain positive benefits that are described in ACI 221R-96 ;(2001) .When they perform below expectation, unsatisfactory concrete may result. Their important role is frequently over looked because of their relatively low cost as compared to that of cementitious materials [31].

Normal-weight aggregates should meet the requirements of ASTM C 33 or AASHTO M 6/M 80. These specifications limit the permissible amounts of deleterious substances and provide requirements for aggregate characteristics. For adequate consolidation of concrete, the desirable amount of air, water, cement, and fine aggregate (that is, the mortar fraction) should be about 50% to 65% by absolute volume (45% to 60% by mass).

A study showed [13] that the physical properties of both fine and coarse aggregates are summaries in Tables 2.6 and 2.7 below.

Table 2.6 Physical Properties of Fine Aggregate.

item no.	Description		Test result
1	* Natural sand		0.60%
	* Manufactured sand		13.4%
2	Dry unit weight		
	* Natural sand		1.57%
	* Manufactured sand		1.47%
3	Moisture content		2.25%
4	Absorption capacity		1.83%
5	Specific gravity	Bulk	2.4

	(gm./cc)	Bulk(SSD)	2.6
		Apparent	2.6
6	Fineness modulus		
	* Natural sand		3.14
	* Manufactured sand		3.14

Table 2.7Physical properties of coarse aggregate

item no.	Description		Test result
Table 2.8 Physical properties of coarse aggregate.			
1	Maximum aggregate size		19mm
2	Flakiness Index (FI)		
	* On 14 mm - 6.3mm		29.25%
3	Elongation		39.04%
4	Moisture Content		0.76%
5	Dry unit weight		1.88
6	Absorption capacity		1.39%
7	Specific gravity (gm./cc)	Bulk	2.6
		Bulk(SSD)	2.8
		Apparent	2.7

Source: Adopted from;Shewaferaw Dinku Belay (July 2006)

Summary and Findings

The following summarizes the findings of previous research work on the effects of aggregate type, size, and content on normal and high-strength concretes:

In high-strength concretes, higher strength coarse aggregates typically yield higher compressive strengths and fracture energy, while in normal-strength concretes, coarse aggregate strength has little effect on compressive strength or fracture energy.

Most researchers conclude that aggregate type has little effect on flexural strength; however, other researchers argue that higher strength coarse aggregates yield higher flexural strengths than lower strength coarse aggregates.

- The shape and the surface texture of aggregates influence the properties of fresh concrete more than the hardened concrete [33].

- Generally, irregular textured, angular, and elongated particles require more cement paste than smooth and rounded particles to produce workable concrete mixture because of higher void contents [23].
- In addition, mixtures with rough textured or crushed aggregates have higher strength, especially tensile strength, at early ages than a corresponding concrete with smooth or naturally weathered aggregate of similar mineralogy since they are assumed to produce stronger physical bond with cement. But, at later ages, the effect of surface texture may be reduced because of the chemical interaction starting to take place between the aggregate and the cement paste. [33].

2.5 Properties of crushed animal bone (CAB) aggregate

The CAB aggregate is calcareous in nature and can bind easily with cement products. Being organic in nature, the properties of CAB aggregate highly differ from the conventional aggregates. The physical properties of CAB aggregate and normal aggregates are presented in Table-2.8 for comparison purposes. From this Table it is observed that bulk density of crushed animal bones CAB aggregates have a unit weight of 7.70-8.25 kN/m3 and this is approximately 35% lighter compared to the conventional aggregates (15.70-22.00 kN/m3). Aggregate having unit weights (of less than) 12.00 kN/m3 are classified as lightweight aggregates [9].Further, it is observed that water absorption value is higher as compared to normal aggregate. In general, most of the lightweight aggregates have higher water absorption `values compared to that of conventional aggregates. Lightweight aggregate with higher water absorptions were recorded for pumice aggregates (volcanic rock) which have a water absorption value of about 37%. However, the high water absorption of CAB aggregate can be beneficial to the resulting hardened concrete. It has been reported that lightweight concrete with porous aggregates (high water absorption) are less sensitive to poor curing as compared to normal weight concrete especially in the early ages due to the internal water stored by the porous lightweight aggregate[4].

Table-2.8 Physical properties of aggregates [3].

Properties	CAB aggregate	Normal aggregate
Maximum aggregate size, mm	20	20
Bulk density, Kg/m3	822	1510

Specific gravity (SSD)	1.61	2.65
Fineness modulus	6.66	6.59
24-hour water absorption (%)	4.00	0.20
Aggregate crushing value (%)	22.0	16.08

Fig.2.4 Shapes of CAB aggregate

The particle size distribution of CAB aggregate and normal aggregates is shown in Figure-2.5 indicating well graded particle size distribution having all types of sizes of aggregate in both types of aggregates. The mechanical properties of bones are presented in Table-2.9 and a typical stress-strain curve resulting from a tensile test conducted on a bone specimen is shown in Figure 2.6for reference [3].The behaviour of bone in uni-axial tension in comparison to other common materials is shown in Figure-2.7.From Table 2.8 it is further observed that the crushing value of CAB aggregate is higher than normal aggregate indicating poor strength of CAB aggregate as compared to normal aggregate.

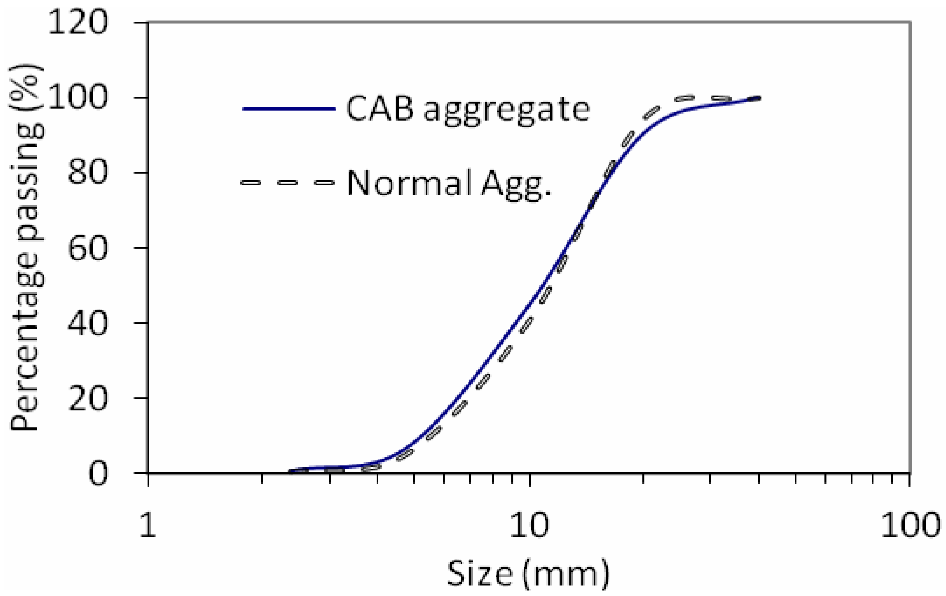

Fig.2.5 Particle size distribution of CAB aggregate.

Table-2.9 An overview (or representative average) of cortical bone properties for human and cow [3].

Property	**Bovine (Cow) value**
Elastic modulus transverse	20.4GPa
Elastic modulus long	11.7GPa
Shear modulus	4.1GPa
Tensile yield stress long	141MPa
Tensile ultimate stress long	145MPa
Tensile ultimate stress trans	50MPa
Compressive yield stress long	196MPa
Compressive yield stress trans	150MPa
Compressive ultimate stress Long	137MPa
Compressive ultimate stress Trans	178MPa
Tensile ultimate strain	0.67-0.72%
Compressive ultimate strain	2.5-5.2%

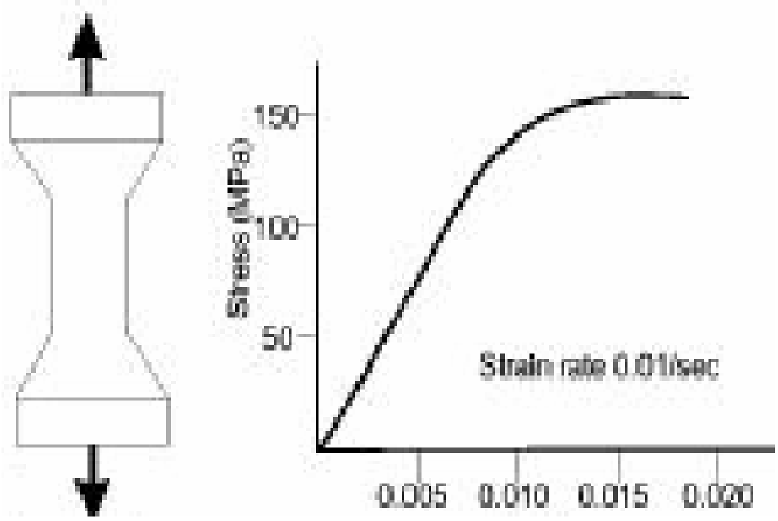

Figure 2.6 Illustration of a bone test specimen and a stress strain curve resulting from a tensile test.

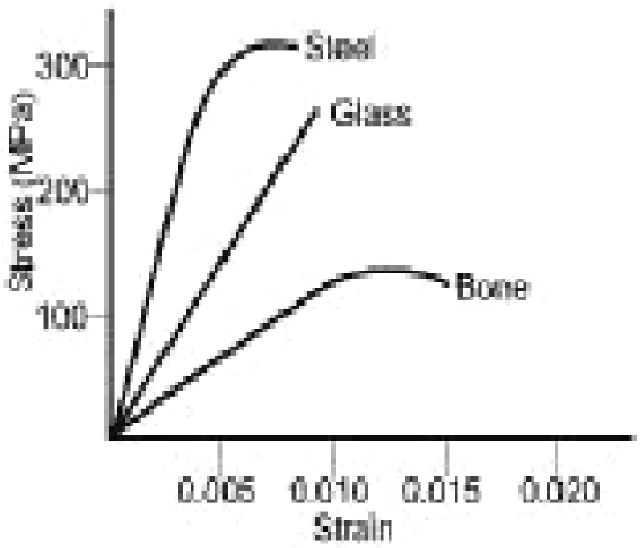

Figure 2.7 Behavior of bone in uni-axial tension compared to other common materials.

2.5.1 Properties of light weight concrete with crushed animal bones

Concrete specimens were prepared replacing normal aggregate by CAB aggregate as coarse aggregate(in percent by weight) in proportion of 100: 0 [coarse aggregate (100%): CAB aggregate (0%)]; 75: 25 [coarse aggregate (75%): CAB aggregate (25%) i.e., 25% of normal aggregates is replaced by CAB aggregate]; 65: 35(i.e., 35% of normal aggregates is replaced by CAB aggregate), 50: 50 (i.e., 50% of normal aggregates is replaced by CAB aggregate), 25: 75 (i.e., 75% of normal aggregates is replaced by CAB aggregate) and 0: 100 (i.e.,100% of normal aggregates is replaced by CAB aggregate). Thus the replacement of normal aggregate by CAB aggregate is in the range from 0% to 100%.Six different mixes (1:1.5:3) were prepared on each for 0%, 25%, 35%, 50%, 75% and 100% replacement levels of normal aggregates by CAB aggregate for casting various specimens viz. cubes (150mm x 150mm x150mm), for computation of compressive strength and unit weights of these concretes. For the purpose of computing above stated properties, a total of 144 cubes were cast, properly cured in water and tested at the age of 7 and 28days. Since the CAB aggregate has a water absorption value of 4% as compared to 0.2% for that of the normal aggregate, there was every apprehension that the CAB aggregate will absorb more water from the mix during mixing operation, thus affecting the workability, water/cement ratio and hence the strength as well. In order to avoid this problem, the CAB aggregate were pre-wetted (soaked) for 24 hours and surface dried.

Workability

As expected, the workability of CAB concrete reduces as the percentage of CAB aggregates increases. This can be attributed to the fact that since the normal aggregates are denser (heavier) than CAB aggregates and the replacement is by weight, the specific surface increases as the CAB aggregate content is increased. Since the CAB aggregates are very light and do not settle (sink) easily, slump test is not a true indicator of workability for CAB concrete. Therefore, workability has been determined by performing compaction factor test.

The reduction in workability of concrete batches for different percentages of CAB aggregates using compaction factor test has been estimated and is shown in Table 2.10. It is observed that there is a reduction in compaction factor up to 9%, however the values of compaction factor still falls in medium workability range(IS: 456-2002). The workability is found to decrease with the increase in the replacement level of the normal coarse aggregates with the CAB aggregates. This can be attributed to the fact that since the normal aggregates are denser than CAB aggregates and the replacement is by weight, the specific surface area increases as the CAB aggregate content is increased. Thus, increase in the specific surface area due to lightness of CAB aggregates and greater amount of water needed for the mix ingredients to get closer packing, results in decrease in workability of mix.

Table-2.10 Reduction in workability of CAB concrete for different percentages of CAB aggregates [3].

CAB aggregate used (%)	0	25	35	50	75	100
Compaction factor	0.896	0.885	0.860	0.847	0.834	0.815
Reduction in compaction factor	-	1.2	4.0	5.5	6.9	9.0

Compressive strength

The compressive strength of concrete cubes made with and without CAB aggregates has been determined at7, 14, 21, and 28 days. The average compressive strength (cube strength) results are shown in Table 2.11. From these results it is observed that compressive strength decreases as the CAB aggregate content increases (as percentage of normal aggregates decrease). As expected, the compressive strength is maximum for specimen with 100% normal aggregate (i.e., no replacement of normal aggregates by CAB aggregates) and minimum when CAB aggregate content is 100%. It is further observed that the minimum 28-day cube strength value of 20 N/mm2 (M-20) as expected for nominal concrete mix 1:1.5:3 could still be achieved with approximately 50% CAB aggregate inclusion. Though the compressive strength achieved by CAB concrete is low, however, lower compressive strengths have been reported for light weight aggregate concretes. The compressive strengths of concrete cube specimens with 50% and 100% periwinkle shells for 1:1.5:3 ratios have been found to be 17N/mm2and 8N/mm2 respectively and the unit weight achieved was 16.05kN/m3 for 100%inclusion of periwinkle shells. Compressive strength can be improved by using silica fume (SF). The SF has been successfully used in the past to improve the bond between the Palm Kernel Shells(PKS) and the cement matrix that could ultimately increase the strength properties of the Palm Kernel Shell Concrete (PKSC).The extremely fine SF particles react with the liberated calcium hydroxide to produce calcium silicate and aluminates hydrates. These both increase the strength and reduce the permeability by densifying the matrix of the concrete. Thus the zone between aggregate and cement paste interface, which is called the zone of weakness, could be strengthened by the use of SF. It has been observed that the strength of PKSC without silica fume generally lies in the range of 15-25MPa. However, with the addition of 10% of silica fume, the strength of 36.5MPa has been reported showing an increase of about39% in compressive strength .Therefore, silica fume can be used in CAB concrete to increase its strength which makes it acceptable for structural members, as some of the codes of practice stipulate minimum strength of lightweight concrete(LWC) as 15MPa.

Table-2.11 Average compressive strength of concrete at 7days and 28 days of testing [3].

%age of CAB in concrete	**Compressive strength at 7 days (N/mm2)**	**Compressive strength at 28 days (N/mm2)**
0	18.93	28.25
25	17.63	26.40
35	16.07	24.36
50	12.38	19.20
75	10.02	16.17
100	8.05	12.37

Unit weight

For structural applications of lightweight concrete, the density is often more important than the strength. The reduction in unit weights of the CAB concrete for various percentages of CAB aggregates and normal aggregate at the age of 28days is shown in Table 2.12. As can be observed from this Table that the average unit weights corresponding to 50%,75%, and 100% of CAB aggregate inclusion in concrete are 19.60 KN/m3, 17.65 KN/m3, and 16.55 KN/m3respectively for nominal concrete mix 1:1.5:3. These fall within the range of lightweight concrete, as lightweight concrete is defined as the concrete whose dry density varies from 14 kN/m3 to 20kN/m3 compared with that of24 kN/m3 for normal-weight concrete (NWC) .

Table-2.12 Variation in unit weight of hardened concrete at28 days age.

Percentage of CAB (%)	**Unit weight (KN/m3)**	**% age reduction in unit weight**
0	2415	0.00
25	2273	6.00
35	2145	11.00
50	1960	19.00
75	1765	27.00
100	1655	31.50

Conclusions on the CAB aggregate

On the basis of results produced the above literature concluded that:

- ✓ Lightweight concrete using CAB aggregate can be achieved by replacing normal aggregate by CAB aggregate approximately 50% or more.
- ✓ The average unit weights corresponding to 50%, 75%, and 100% of CAB aggregate inclusion in concrete are 19.60 KN/m3, 17.65 KN/m3, and 16.55 KN/m3respectively, for nominal concrete mix 1:1.5:3.
- ✓ Compressive strength of CAB concrete (lightweight) is low as compared to normal concrete; however, it can be improved by using silica fume (SF).
- ✓ Besides achieving economy in construction, by reducing the weight of the structure, the catastrophic earthquake failures caused due to inertia forces (earthquake forces are proportional to the weight of the structure) that influence the structures can also be ultimately reduced.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study area

Jimma zone is one of the thirteen zones of Oromia regional, state which geographically lies in south western part of Ethiopia. Jimma Town is the capital of the zone that is 345 km far away from Addis Ababa, capital city of Ethiopia. It covers a total surface area of 19,305.5 km^2. 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 topographical features elevation 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 Jimma zone: There is the reason to choose Jimma Zone as the study area; that this research were conceded to find and gives the alternative construction material, especially in the case of concrete making ingredients. In these zones the construction project has appears fast and actively developing. In addition to this Ethiopia is 5th country in the world and the 1st country in Africa in number of cattle and supplies 500-1000 number of cattle per week for the meat market [3]. This study therefore is carried out in Jimma Zone and focuses on the use of crushed animal bones CAB aggregate for the construction projects as conventional concrete materials. In addition it has a great contribution in abattoir house waste minimization and environmental conservation.

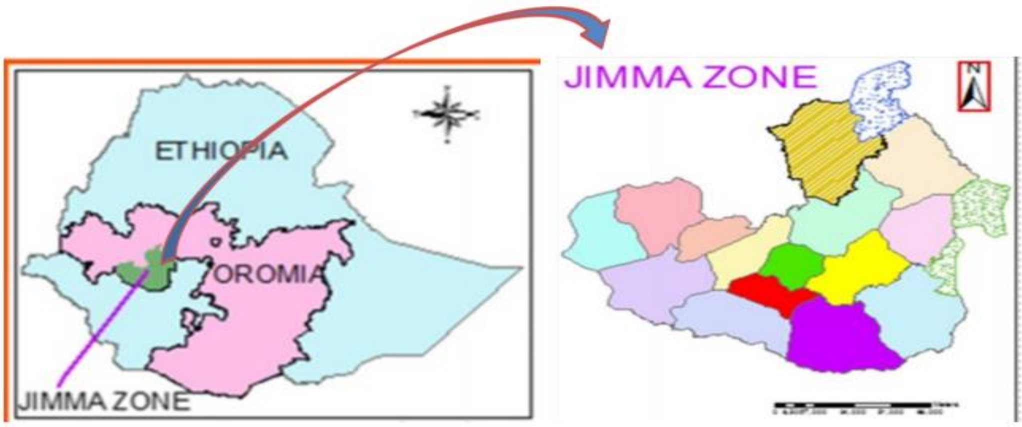

Figure 3.1 Map showing the geography of study districts.

3.2 Materials

3.2.1 Water

The water content of concrete is influenced by a number of 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.

3.2.2 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 3.1 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 %	-

3.2.3 Coarse Aggregate

The objective of this study was to determine the engineering properties and characteristics of crushed coarse aggregate and crushed animal bone aggregate around the Jimma zone.

For this study two types of coarse aggregate were used; as follows; Table 3.2 shows Type and source of aggregates that were tested for aggregate characterization tests.

Table 3.2 Type and source of aggregate

No.	Aggregate type	Source
1	Crushed Coarse Aggregate (CCA),	Locally available aggregate
2	Crushed animal bone aggregate(CAB)	Collected from abattoir houses in Jimma town
3	Fine aggregate (natural sand)	Gambella sand

Figure 3.2 CCA field sample

Crushed coarse aggregate with a maximum size of 20 mm, specific gravity of 2.48 and complying with ASTM C-33 was used as crushed coarse aggregate in this study. While crushed animal bone aggregate (CAB) was obtained from different sources randomly (abattoir houses) and has a specific gravity of 2.41 complying with ASTM C-330.

Figure 3.3 Crushed animal bone aggregate (CAB)

Sample

3.2.4 Natural Sand

River sand with predominantly a specific gravity of 2.63 was used as fine natural aggregate in this study. Natural sand was brought from Gambella which is one of the 9 states of Ethiopia; located about 715 km away from the capital city of Ethiopia; Addis Ababa and 369 km from Jimma

3.3 Study Design

To investigate the quality and availability of suitable concrete making aggregates in Jimma Zone, test results of coarse aggregate and fine aggregate samples were collected from JIT Materials Testing Laboratories in Jimma. The collected data consists, test results of 2 boxes fine aggregate samples of Gambella sand from market and 3 boxes of samples from 2 different sources (CCA AND CAB). The research program was divided into two main phases as outlined below:

Phase1

In phase 1, the aggregate collected from their source (see table 3.2.) in the laboratory was tested to determine its physical and mechanical properties. The tests were carried out in accordance with the appropriate ASTM, AASHTO, ACI, ES and BS were applicable (Appendix A). With this understanding, the requirements of the properties of crushed animal bone aggregate for specific application and performance of normal weight concrete can be established. This would allow for a performance approach to classification of crushed animal bone aggregate and also used for comparison between (crushed natural aggregate and crushed animal bone aggregate) with in accordance with the appropriate standards.

Phase 2

In phase 2, the two aggregate types (crushed coarse aggregate and crushed animal bone aggregate) were used to produce normal weight concrete and also comparison was made with two different coarse aggregate mix of concrete. Concrete specimens were prepared replacing normal aggregate by CAB aggregate as coarse aggregate(in percent by weight) in proportion of 100: 0 [coarse aggregate (100%): CAB aggregate (0%)]; 90: 10 [coarse aggregate (90%): CAB aggregate (10%)]; 75: 25 [coarse aggregate (75%): CAB aggregate (25%) i.e., 25% of normal aggregates is replaced by CAB aggregate];50: 50 (i.e., 50% of normal aggregates is replaced by CAB aggregate),25:75 (i.e., 75% of normal aggregates is replaced by CAB aggregate) , and 0:100 (i.e.,100% of normal aggregates is replaced by CAB aggregate). Thus the replacement of normal aggregate by CAB aggregate is in the range from 0% to 100%.three different mixes (1:2.03:2.67) were prepared on each for 0%, 10%, 25%, 50%, 75%and 100% replacement levels of normal aggregates by CAB aggregate for casting various specimens viz. cubes (150mm x 150mm x150mm), for computation of compressive strength of these concretes. For the purpose of computing above stated properties, a total of 36 cubes were cast, properly cured in water and tested at the age of 7 and 28days. For phase 1 and 2, tests were planned and carried out as detailed in the following sections.

3.4 Experimental Work Procedures of Aggregate

3.4.1 Properties of Coarse Aggregate

The physical and mechanical properties of the coarse aggregate collected from the two different sources or locations of the stockpiles, hereinafter stated as sources CCA and CAB, were determined in the laboratory according to the test methods specified in table 2 in appendix A. For each types of aggregate according to AASHTO T 2, and ASTM D 75 the field 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.

1. **Sieve Analysis**

The grading is determined in accordance with ASTM C 136, “Sieve or Screen Analysis of Fine and Coarse Aggregates.” A sample of the aggregate is shaken through a series of 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 No.67 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 specific sieves for the No.67 gradation. A plot of the low, average and upper values of the No. 67 gradation is shown in (appendix B).During this test; the laboratory sample was taken by reducing the field sample with sample Riffling technique.

(a) CCA (b) CAB

Figure 3.4 Samples Reducing for Lab Test

2. **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 generally accepted test procedures. The particle densities and water absorption are calculated according to the following equation provided in the standard:

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

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

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

Where

A = mass of oven-dry sample in air;

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

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

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

Where

W = mass of the original sample, and

W_{OD} = mass of the dried sample.

3. **Bulk density (unit weight)**

The bulk density of the aggregate was determined according to ASTM C29. 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 3.5 the Bulk Density of the Coarse Aggregate Test

The bulk density (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, roding each layer 25 times with a tamping rod, levelling 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.

The bulk density (ρb) is calculated for each test specimen from the equation.

Unit Weight (Kg/m3) = $\frac{B-A}{C}$

Where

A = Mass of Container (Kg)

B = Mass of Container + Sample (Kg)

4. Moisture Content

Moisture Content of coarse aggregate was determined in accordance with 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 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. The moisture content mc is calculated from the equation,

Total Moisture Content, %= $\frac{W-WOD}{WOD} * 100$

Surface moisture content—Surface or free moisture content of an aggregate can be determined by subtracting the absorption from the total moisture content.

3.4.2 Properties of fine Aggregate

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

1. **Sieve Analysis; Gradation ASTM C136**

The grading was determined in accordance with 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 3.6 A Series of Sieves Standard Test Apparatus

2. **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.

$$FM=\sum \% \frac{\text{retained}}{100}$$

3. 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 mould and tamped. If surface moisture is still present, the fine aggregate will retain its moulded shape after the mould 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.

Figure 3.7 Fine Aggregate Bulk SSD Test

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

These values are then used tocalculate bulk specific gravity, bulk SSD specific gravity, ap parent 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

4. **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 % $=\frac{\mathrm{WSSD}-\mathrm{WOD}}{\mathrm{WOD}}*100$

5. **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 % $=\frac{W-WOD}{WOD} * 100$

3.5 Mix Design

To see the effect of a variety of coarse aggregates, whose maximum size 20 mm were prepared mix designs for concretes made with aggregates of different properties were used. The coarse aggregate gradations employed are designated as No. 67in accordance with prevailing specifications by the ASTM C-33.

- Crushed Coarse Aggregate (CCA) and Crushed animal bone aggregate (CAB)was used, thereby resulting in two mixes, which were designated as follows:
- Mix By Crushed Coarse Aggregate (CCA),
- Mix By Crushed animal bone aggregate (CAB),
- 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.

Except the control (0:100) or with no crushed animal bone, Each mix of concrete is composed of crushed coarse aggregate, crushed animal bone aggregate ,natural sand, ordinary Portland cement, and water.

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 3.3 Properties of aggregate samples used for the mix design

Engineering Properties of Aggregate Used in the Study		Crushed coarse aggregate		Standard Specification
		(CAB)	(CCA)	
1	Specific Gravity (SSD)	2.41	2.48	ASTM C 127 2.4-2.9
2	Water Absorption (%) (SSD)	4.0	1	ASTM C 127 0.2% to 4%
3	Dry-Rodded Unit Weight (kg/m3)	788.25	1554.25	ASTM C 29M – 97 1200-1750 <1200 N/m3(light weight)

Properties of fine aggregate				
			Standard Specification	
	Unit weight (kg/m3)	1434.33	ASTM C -29	1520 – 1680
	Fineness modulus	2.69	ASTM C 136	2.2-3.1
	Specific gravity	2.63	ASTM C128	2.30 to 2.90
	Absorption, %	0.74	ASTM C128	0.2 to 2
	Free moisture content, %	0.8	ASTM C70-79	2 to 6
	Loose unit weight (Kg/m3)	1323	ASTM C -29	1520 – 1680
	Specific gr. Of Cement (O.P.C)	3.15	ASTM C 150	

1. **Mix design procedure (ACI 211.1-91)**

Crushed Coarse Aggregate (CCA) and crushed animal bone (CAB) aggregate (Designation of the samples is given in APPENDEX C-1.1)

Step 1 collected data for mix design:-

Fineness modulus of selected fine aggregate =2.69

Unit weight of dry rodded coarse aggregates =1554.25kg/m3

specific gravity of coarse and fine aggregate in saturated surface dry condition is 2.48 and 2.63 respectively

Absorption characteristic of both coarse and fine aggregate is 1.0%and 0.74% respectively

Specific gravity of ordinary Portland cement =3.15

Free surface moisture in sand =0.8%

Step 2 Determination of water to cement ratio

From the strength point of view the estimated water to cement ratio is 0.62 and

From the exposure condition the estimated water to cement ratio is 0.5

Therefore, adopt water to cement ratio of 0.5.

Step 3 Maximum size of aggregate and workability

Maximum size of coarse aggregate is 20mm.

Slump of concrete is 50mm.

Step 4 target mean strength

f'cr,=f'c+8.5

f'cr=25+8.5=33.5M

(ACI318M;Table5.3.2.2 Appendix C)

Step 5 cement content

For the slump of 50mm and 20mm maximum size of aggregate, the maximum water content is 185kg/m^3

cement content =185/0.5=370Kg/m^3

Step 6 weight of corse aggregate

From ACI table 11.4 for maximum size of 20mm coarse aggregate and fineness modulus of sand 2.69,

The dry rodded bulk volume of coarse aggregate is 0.63 per unit volume of concrete.

The weight of coarse aggregate = 0.63*1554.25Kg/m3=979.177kg/m^3

Step 7 weight of fine Aggregate

From ACI table 11.9 the first estimate of density of fresh concrete for 20mm maximum size of aggregate

and non air entrained concrete =2355kg/m^3

Weight of fine Aggregate =2355-(185+370+979.177)=820.823Kg/m^3

Item no Ingredient	ingredients	Weight	absolute volume (cm3)
1	Cement	370	$128*10^3$
2	Water	185	$185*10^3$
3	Gravel	979.177	$394.829*10^3$
4	Air		$20*10^3$

Therefore ,absolute volume of fine aggregate =(1000-717.289)*10^3=282.711*10^3

Weight of fine aggregate =282.711*2.63=743.529 Kg/m^3

Step 8 proportions

Ingredients	Cement	Sand	Gravel	water
Quantity				
(kg/m3)	370	743.529	979.177	185
Ratio	1	2.0	2.65	0.5
One bag Cement	50 Kg	100Kg	132.5Kg	25Kg

Step 9 Adjustment for field condition

Fine aggregate has surface moisture of 0.8%.

Weight of fine aggregates =(743.529+0.008*743.529)Kg/m3=749.477Kg/m^3

Coarse aggregate absorbs 1% of water.

Weight of coarse aggregate=(979.177+0.01*979.177)Kg/m3= 988.969Kg/m^3

Adjust the amount of water based on moisture content

the required mixing water =(185-749.477 (0.008-0.012)- 988.969 (0.013-0.01))Kg/m^3

=179.035Kg/m^3

Step 10 Final design proportion

Ingredients	Cement	Sand	Gravel	water
Quantity				
(kg/m3)	370	749.477	988.969	179.035
Ratio	1	2.03	2.67	0.5
One bag Cement	50 Kg	101.5Kg	133.5Kg	25Kg

3.6 Tests on Fresh Concrete and Hardened Concrete

3.6.1Fresh Concrete

A. Slump

The test was performed by following ASTM C 143/C Standard Test Method for Slump of Hydraulic-Cement Concrete. A 30 cm 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 3.8 Different Possible Slump Test Results.

Figure 3.9 Measuring Slump of Fresh Concrete Mix

B. Casting

In order to cast the required number of specimens, 6 Cubes for each mix was used. The concrete was cast into different kinds of mix at 0%, 10%, 25%, 50%, 75% and 100% replacement with (150mm*150mm*150mm) cubical specimens. The cubical mould was used for testing of compressive strength at 7th and 28th with water immersion curing technique. Twenty-four hours after casting, the specimens were demoded, labelled, and placed in a mixture of water at room temperature to cure.

Figure 3.10 Typical 150 mm Cube Mould

3.6.2 Hardened concrete

Compressive Strength of Concrete

Compressive strength tests were performed on 150 mm concrete cube specimens at the ages of 7 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 3.11 at a loading rate of 200KN/min. The average of the 3 specimens was taken as the compressive strength of the concrete.

Figure 3.11 Compression Test Machine And Test Sample

CHAPTER FOUR

RESULTAND DISCUSSION

4.1 Aggregates

The major 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's objective was to determine the Engineering properties of Crushed coarse aggregate and crushed animal bone aggregate for the requirements of C-25 Concrete around the Jimma zone. This study obtained two different coarse aggregates(Crushed coarse aggregate and crushed animal bone aggregate) samples conforming to the designated specifications was used and thereafter conducted the following laboratory tests on some of their properties to determine their fitness for use in producing concrete.

1. **Gradation of Samples**

Table 4.1 Average Sieve Test Result for CCA

Aggregate type Size Number (#67)	Sieve size (mm)					
	25	19.0	9.5	4.75	2.36	0.075
%pass(CCA)	100	92.55	23.52	3.51	1.74	0.09
%Coarser		7.45	76.48	96.49	98.26	99.91
ASTM C-33 upper limits	100	100	55	10	5	0
ASTM C-33 lower limits	100	90	20	0	0	0

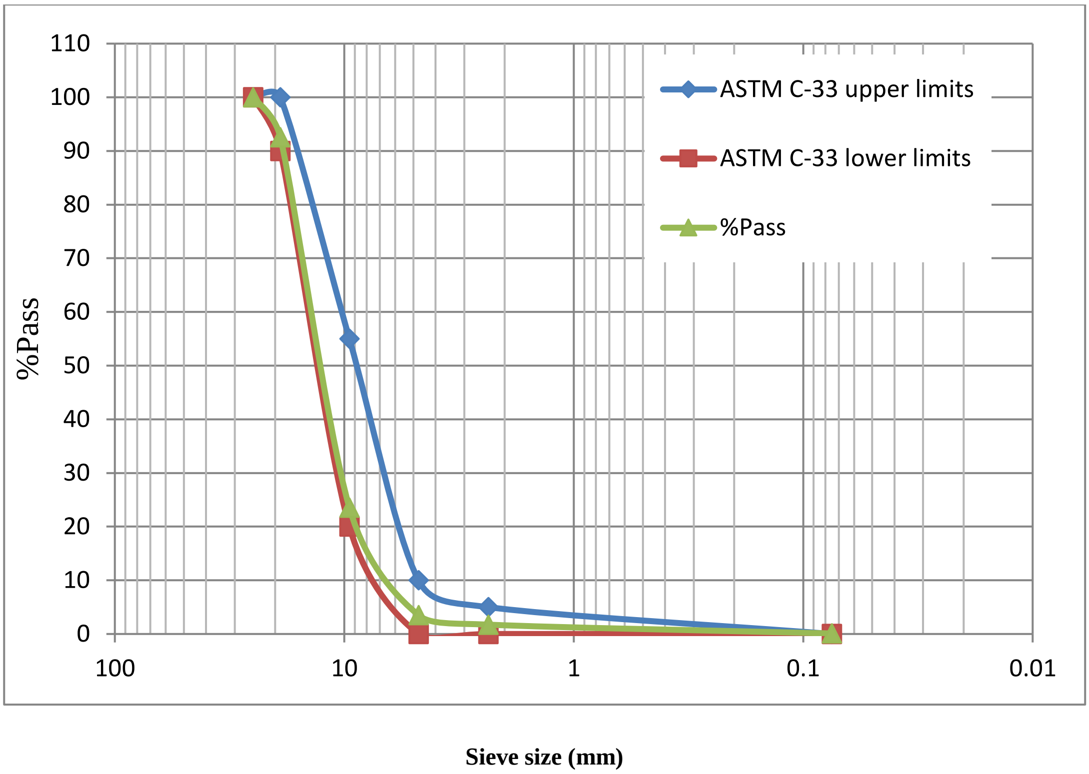

Figure 4.1 Average Gradation Curves for CCA

The results for average particle size distribution of crushed coarse aggregate are summarized and presented in table 4.1 and figure 4.1. It was observed that the crushed coarse aggregate were fall within the limits specified by ASTM C-33 standards. As shown in Table 4.1, the percentage passing sieve 19.0 through 2.36 were 92.55 and 1.74 which was meet the gradation specifications for ASTM C33 (100-90 and 5-0%) grading requirements for coarse aggregates designation No. 67 aggregate. Also from the figure, it was seen that the percentage passing curve for sieve19 through 9.5mm were slightly closer to the lower limits of ASTM C-33 and it indicated that crushed coarse aggregate is coarser than fine content at this point but from 4.75 to 2.36 mm percentage passing between upper and lower limits.

Table 4.2 Average Sieve Test Result for CAB

Aggregate type Size Number (#67)	Sieve size (mm)					
	25	19.0	9.5	4.75	2.36	0.075
% Pass (CAB)	100	91.54	34.65	6.93	1.38	0.03
% Coarser		8.46	65.35	93.07	98.62	99.97
ASTM C-33 upper limits	100	100	55	10	5	0

ASTM C-33 lower limits	100	90	20	0	0	0

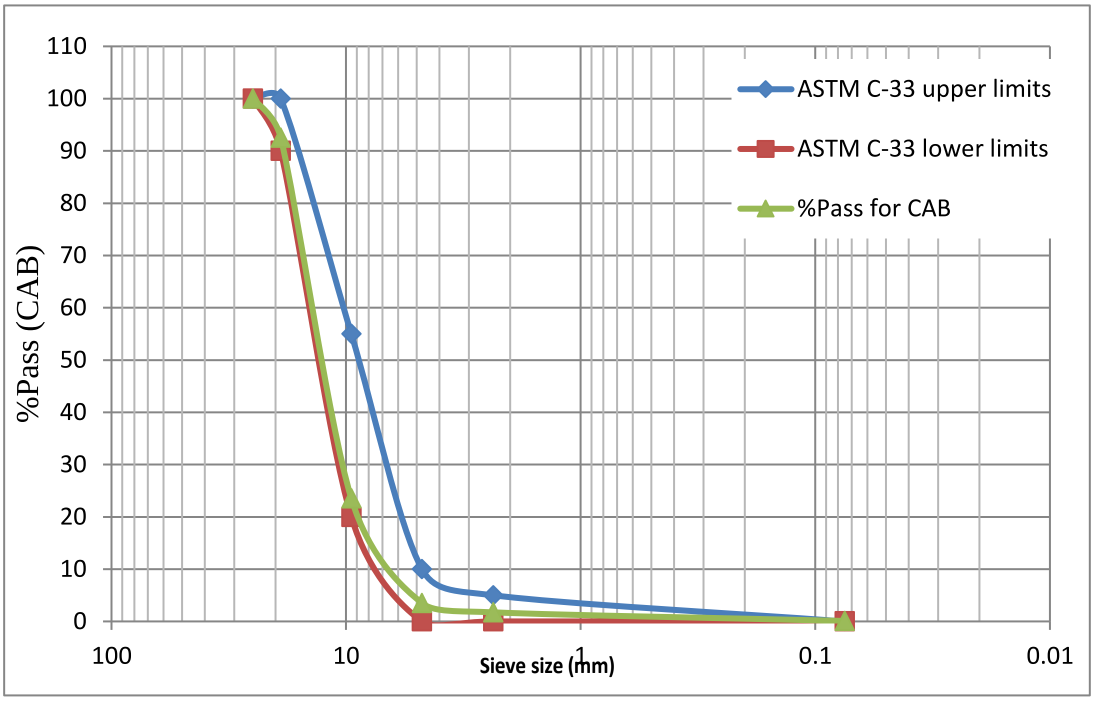

Figure 4.2 Average Gradation Curve for CAB

Table 4.2 shows the average test results for the sieve analysis of the used; whereas figure 4.2 shows the graphical representation of the result. The result revealed that the crushed animal bone aggregate were falling within the gradation specifications for ASTM C33/C 33M grading requirements for coarse aggregates designation No. 67 aggregate. It can be seen in figure 4.2 shows as the curves of the crushed animal bone aggregate were the percentage passing on sieve No 19.0 mm was 91.54% which is close to the lower limits means coarser at this point while the percentage passing curve for sieve9.5 through 4.75mm were somewhat between to the upper and the lower limits of ASTM C-33 and it indicated that crushed animal bone aggregate well graded.

Table 4.3 Different Coarse Aggregate Sieve Analysis Test Result

Aggregate type	Sieve size (mm)						
	25	19.0	9.5	4.75	2.36	0.075	Pan
CCA	100	92.55	23.52	3.51	1.74	0.09	0.00
CAB	100	91.54	34.65	6.93	1.38	0.03	0.00
ASTM C-33	100	100-90	55-20	10-0	5-0	0-1.5	

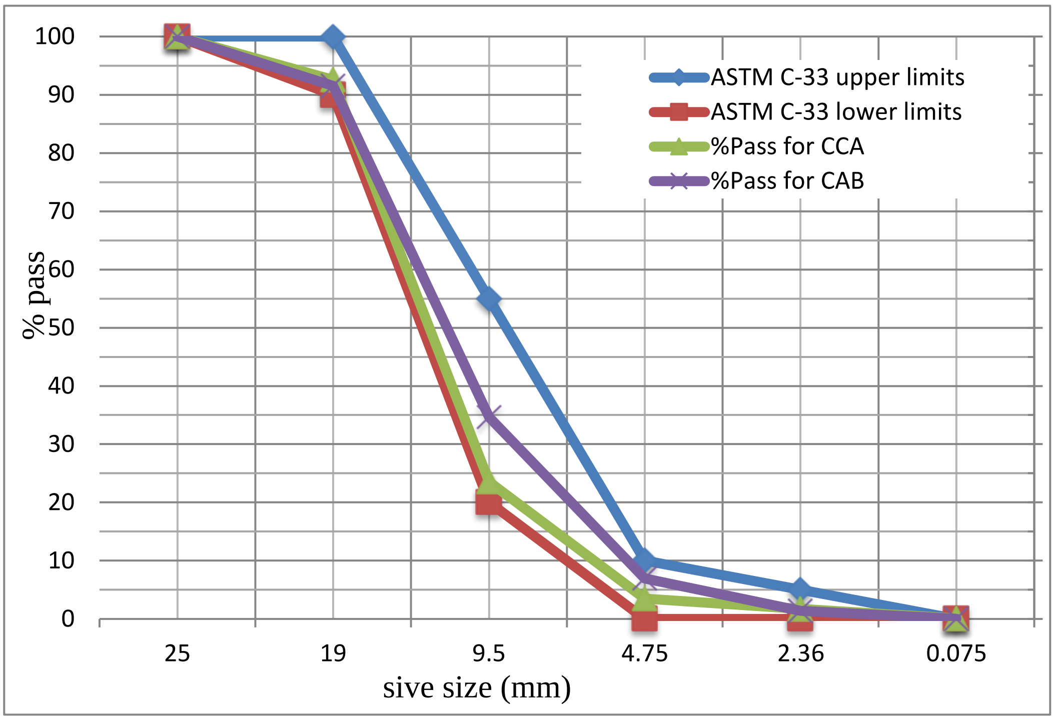

Figure 4.3 The percent passing on the No. 200 sieve for two coarse aggregate types.

As shown in table 4.3, the percentage passing through the 4.75mm sieve for the CCA gradation was increased by 8.07 % (i.e., from 3.51 % to 11.58 %) and 3.42 % (i.e., from 3.51 % to 6.93 %) for CAB aggregate .These Surpluses in the (at 4.75mm) CAB aggregate gradations was followed by a subsequent decrease in the quantity of their 9.5 mm CCA by 8.07 % (i.e., from 4164 % to 23.52 %) and 3.42 % (i.e., from 34.65 % to 23.52 %), respectively., Also the result is shown in the figure, 4.4 indicated that both CCA coarse aggregate is percentage passing on sieve No 19mm were 92.55%, whereas the crushed animal bone aggregate had 91.54% with a difference of 1.01%; for small quantities of fine or coarse particles can significantly affect the deviations in the test results.

Table 4.4 Average Engineering Properties of Coarse Aggregate

Engineering Properties of Aggregate		Crushed coarse aggregates		Standard Specification
		CCA	CAB	
1	Specific Gravity (SSD)	2.48	2.41	ASTM C 127 2.4-2.9

2	Water Absorption (%)(SSD)	1.0	4.0	ASTM C 127 0.2% to 4%
3	Dry-Rodded Unit Weight (kg/m3)	1554.25	788.25	ASTM C 29M -97 1200-1750

2. Relative Density (Specific Gravity) and Absorption of Coarse Aggregate

Tests for the specific gravity and absorption characteristics of aggregates have long been used to aid in determining batch quantities for concrete,

Table 4.5 Shows the Average Absorption Capacity and Specific Gravity of the Aggregate.

	Crushed Coarse Aggregate (CCA)			Average Result
	Description	Test 1	Test 2	
1	Absorption	1.02	0.98	1.0
	Apparent Specific Gravity	2.596	2.592	2.6
	Bulk Specific Gravity	2.4	2.48	2.44
	Bulk Specific Gravity (S.S.D basis)	2.46	2.5	2.48
2	Crushed anima bone Aggregate (CAB)			
	Description	Test 1	Test 2	Average
	Absorption	5.54	2.46	4.0
	Apparent Specific Gravity	2.58	2.42	2.5
	Bulk Specific Gravity	2.03	2.71	2.37
	Bulk Specific Gravity (S.S.D basis)	2.38	2.44	2.41

a. Specific Gravity

ASTM C 33 #67 crushed animal bone aggregate and crushed coarse aggregate were used for all concrete mixes. Table 4.5 and figure 4.4 reveals the values of the specific gravities and absorption of coarse aggregate (*Saturated Surface-Dry* basis) used in the investigation in accordance with the specifications of ASTM C-127.

As indicated from literature (ACI Education Bulletin E1-99), the standard specific gravity of bulk specific gravity of normal weight aggregates used in concrete is ranges from 2.30 to 2.90. From the results of experiment conducted and presented in table 4.6, sample CCA met the specified standard with specific gravity values of 2.48. However, when the average specific gravity of CAB given as 2.41, which was less than compared to CCA. The low specific gravity of the crushed animal bone shows that it is an impervious light weight aggregate. The porosity and the weight of the gravel account for its high specific gravity. But all the two aggregates are within the ranges for the specific gravity of aggregates requirements according to ASTM C 33 are ranges from 2.4 to 2.9 for normal weight aggregates.

b. Water Absorption

The water absorption of the crushed coarse aggregate and crushed animal bone aggregate vary greatly as shown in table 4.5 and figure 4.4. From the results, the crushed animal bone aggregate samples have higher water absorption capacity as compared to crushed coarse aggregate.

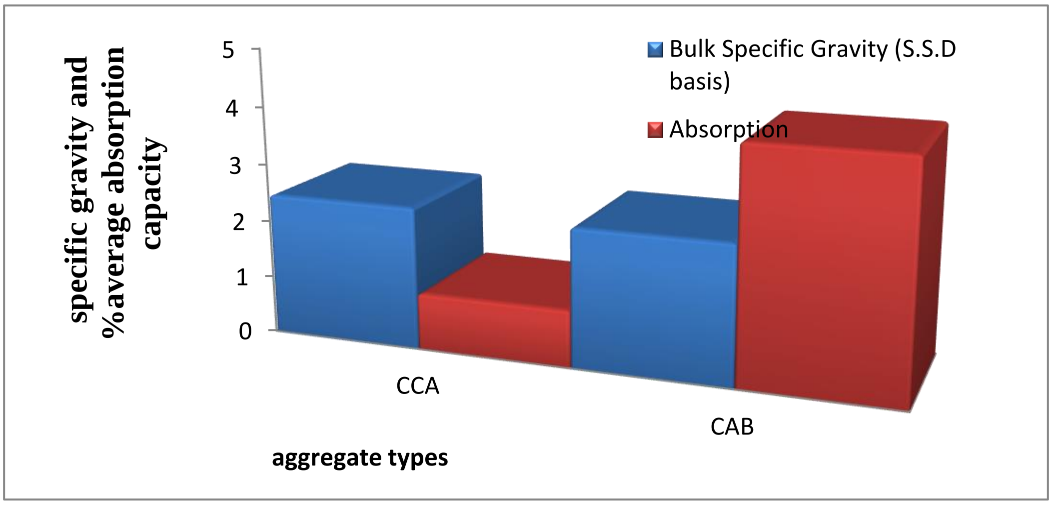

Figure 4.4 Average Absorption Capacity and Specific Gravity of coarse Aggregate**.**

Also figure 4.4 shows as the relation between absorption capacity and specific gravity of the aggregate. The higher specific gravity, the lower water absorption capacity, for these case the higher specific gravity were founded by crushed coarse aggregate with values of 2.48 and 1.0 percent water absorption capacity which are less with compared to crushed animal bone aggregate. According to ACI E-701 2007 aggregate with high value gives good quality of concrete; i.e. means the amount of light weight and impurities are less with compared to aggregate with less amount of specific gravity or the CAB aggregate.

3. Dry-Rodded (Unit Weight)

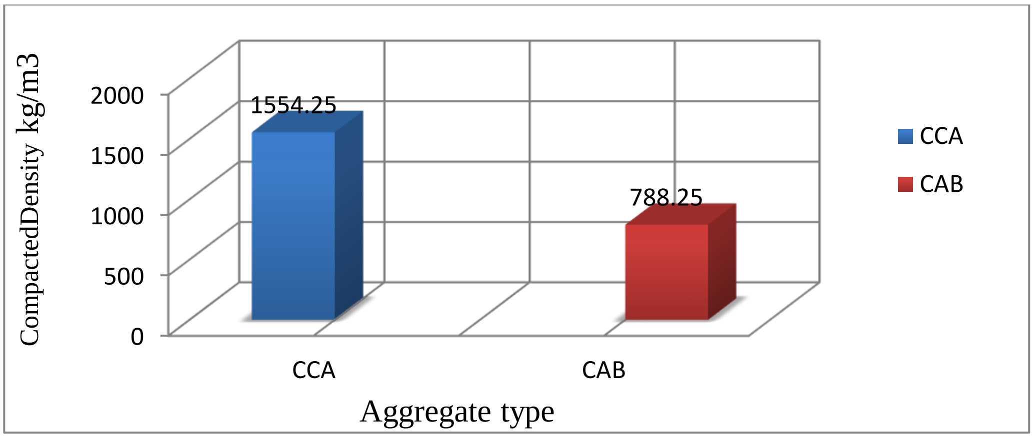

Figure 4.5 Average Compacted Density for Different coarse aggregate

Figure 4.5 shows that all the two samples have satisfy the approximate bulk density of aggregate commonly used in normal-weight concrete ranges from about 1280 to 1920 kg/m3 given in (ACI Education Bulletin E1-99). The dry rodded unit weight of the crushed animal bone aggregate was lower as compared to crushed coarse aggregate (788.25 kg/m3 compared to 1554.25). The reason could be the presence of light weight substance in crushed animal bone aggregate or less compactable and hence may produce less a dense concrete.

4.1.2 Fine Aggregates

The fine aggregate samples were selected (purposively) collected from Jimma city aggregate supplying enterprise.

1. **Sieve Analysis**

Table 4.6 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
	9.5	100	lower	upper	
4	4.75	97.48	95	100	Passed
8	2.36	94.09	80	100	Passed
16	1.18	84.24	50	85	Passed
30	0.6	49.12	25	60	Passed
50	0.3	27.34	10	30	Passed
100	0.15	6.65	2	10	Passed
200	0.075	1.57	0	5	Passed
Pan		0.00	0	0	

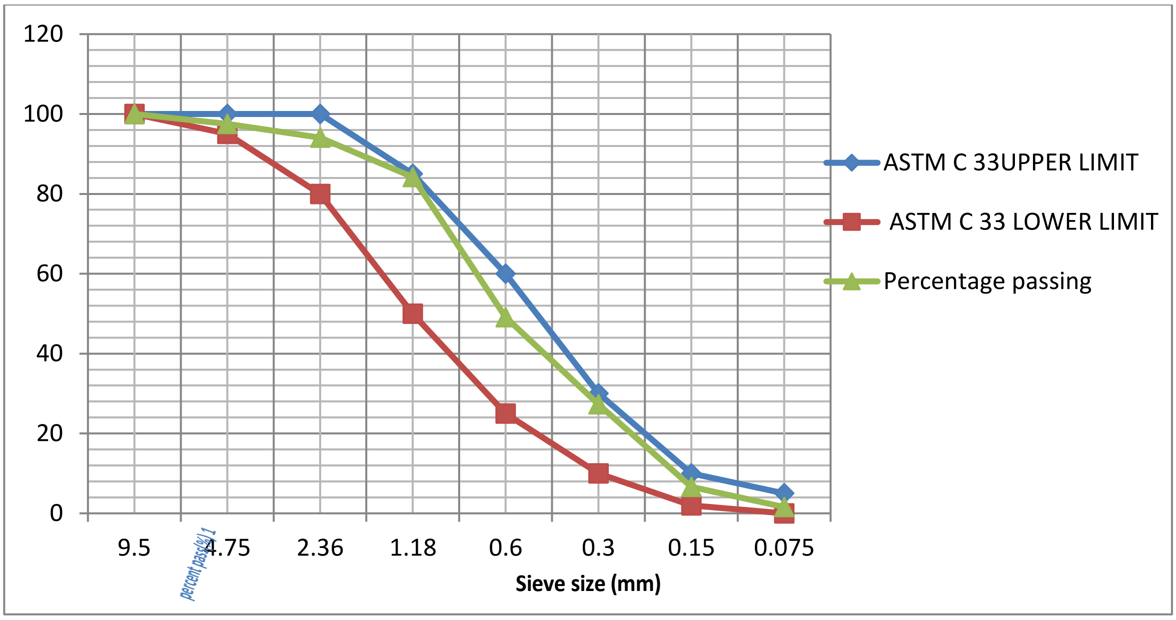

Figure 4.6 Average Grading Curve Test for Fine Aggregates

The results for the sieve analysis test on the aggregates are shown in figure 4.6. The grading curve for the aggregates falls within the lower and upper limit of the grading requirement for aggregate from natural sources ERA and *ASTM C 33*. This implies that the aggregates are suitable for construction work. The gradation of the sample was determined in accordance with ASTM C 136-96a, "Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates." In the study the aggregates were tested in the as-received condition, meaning the aggregates were not re combined to achieve a specific gradation. The results of the analysis are summarized in table 12 and (Appendix B)

2. 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 is. The result of the fineness modulus of the fine aggregate samples summarized as follows;

Table 4.7 Calculation of Fineness Modulus of Fine Aggregate

Sieve size Total	Percent retained (X1)	100-X	X
9.5 mm (3/8 in.)	0.0		

4.75 mm (No. 4)	95.48	100-95.48	4.52
2.36 mm (No. 8)	91.09	100-91.09	8.91
1.18 mm (No. 16)	84.24	100-84.24	15.76
600 mm (No. 30)	39.12	100-39.12	60.88
300 mm (No. 50)	17.34	100-17.34	82.66
150 mm (No. 100)	3.65	100-3.65	96.35
Sum$\sum X$			269.08
FM=$\frac{\sum X}{100}$ = $\frac{269.08}{100}$**= 2.69**			
ASTM C33/C33M	o 2.31		

3. **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 4.8. According to ASTM C-*33* the compacted bulk density of aggregates used for normal weight concrete generally 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 4.8.This indicates that the fine aggregate is stable for construction work.

Table 4.8 The Value of the Compacted Bulk Density of Fine Aggregate.

Description		Trial No			Average
		1	2	3	
Unit Weight Kg/m3	(B – A) / C	1400	1430	1473.33	1434.33
ASTM C29/C29M limit	To 1434.33 kg/m3				

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

Table 4.9 Specific Gravity of the Fine Aggregate Samples

No.	Description	Trial			ASTM
1	Relative density (specific gravity)	Test 1	Test 2	Average	C-128
	Apparent Specific Gravity	2.611	2.777	2.694	2.4 to 2.90
	Bulk Specific Gravity	2.475	2.631	2.553	2.30 to 2.90
	Bulk Specific Gravity (S.S.D basis	2.577	2.683	2.630	2.4 to 2.90
2	Absorption	0.75	0.73	0.74	0.2% to 2%,

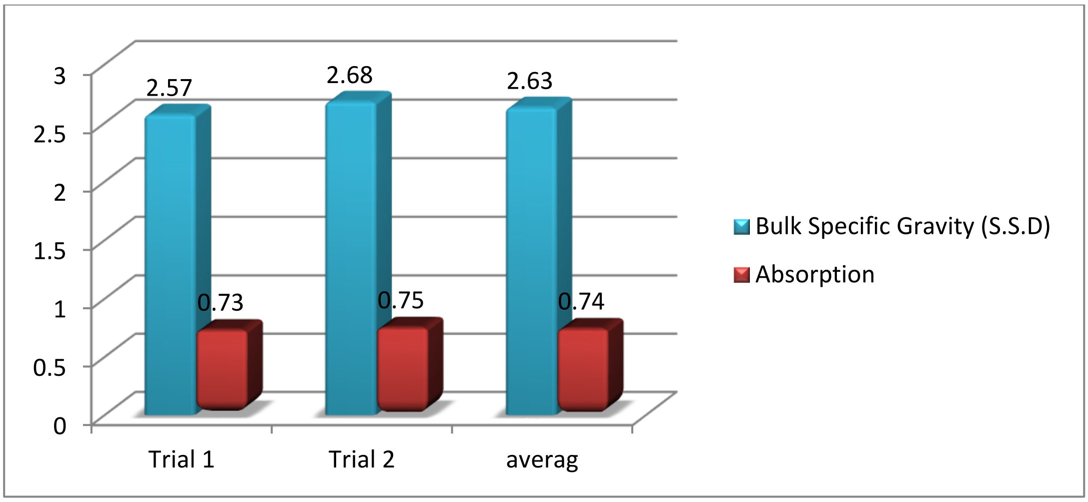

Figure 4.7 Average Absorption Capacities and Specific Gravity of Fine Aggregate.

The values of the specific gravities (SSD) of the fine aggregates are ranges from 2.30 to 2.90 in accordance with the specifications of ASTM C 128.These values are showed in table 4.9 and figure4.7 reveals the relative Density or Specific Gravity of fine aggregates used in the investigation were 2.63, which indicates that the fine aggregate is stable for construction work. Table4.9 reveals the absorption of fine aggregate in accordance with ASTM C 128-97, “standard test method for specific gravity and absorption of in aggregate”. The figure shows that the natural sand used for the experiment was conforming ASTM C 128-97 standard with values 0.74%.

4.2 Concrete Test

4.2.1 Mix Design

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

1. **Fresh Properties of Concrete Mixes**

Workability Test

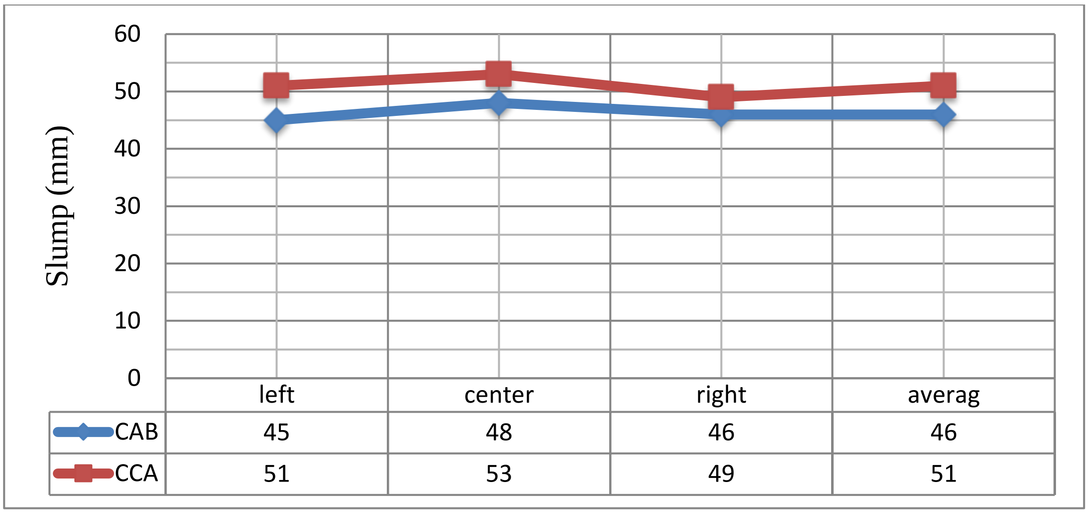

Figure 4.8 Slump Test for Various Concrete Mixes

The tests were carried in two different mixes with the same W/C, cement type and sand. Also the measure was taken in three different points (right, centre and left side) for each mix sample. Workability of concrete mixes increased with crushed coarse aggregate and crushed animal bone aggregate correspondingly. The slump value of the concrete made using crushed coarse aggregate and crushed animal bone aggregate are 50mm and 45mm, with the same water to cement ratio were used. Figure4.8 shows a graphical representation of slump height. According to the result, the lowest slump obtained was 45 mm for crushed animal bone aggregate content mix and the highest slump was 50mm for crushed coarse aggregate mix, for C-25 grade concrete mix. And the investigation envisages the properties of fresh and hardened concrete were studied on the mixes considered. The high friction caused by the rough texture and the angular shape of the crushed animal bone aggregate was thought to be the main reason for low slump.

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. But the workability is higher in concrete mixes with crushed coarse aggregate (zero percent crushed animal bone replacement) rather than crushed animal bone aggregate because of its light in weight. As expected, the workability of CAB concrete reduces as the percentage of CAB aggregates increases. This can be attributed to the fact that since the crushed course aggregates are denser (heavier) than CAB aggregates and the replacement is by weight, the specific surface area increases as the CAB aggregate content is increased.

Mechanical Properties of Hardened Concrete

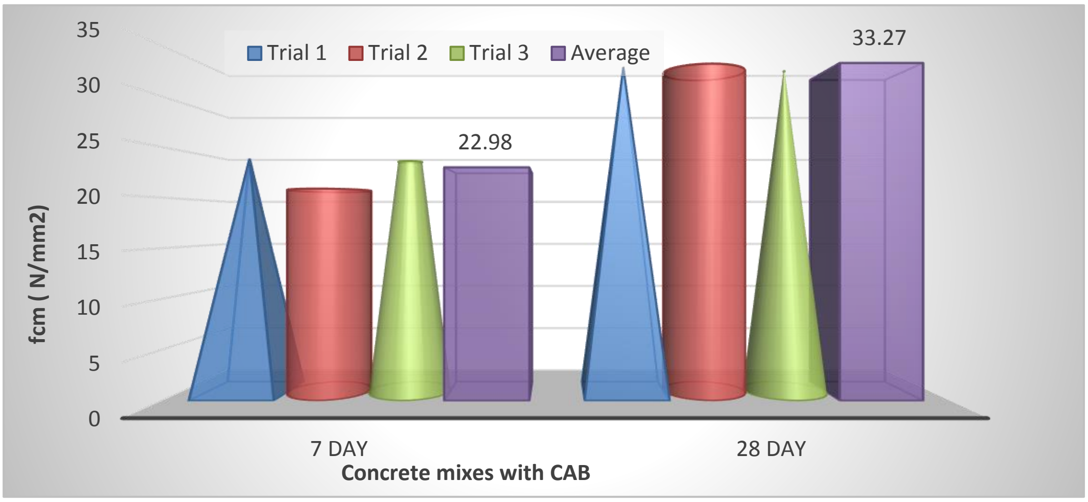

Figure 4.9 Results of Compressive Strength for CAB Concrete Mixes

Figure 4.9 shows the development of compressive strength of concrete mixes with 10% replacement of crushed animal bone aggregate, under different types of curing environments for up to a period of 28 days. The maximum 28-day strength of water cured specimen of about 33.27 MPa was achieved for mix CAB that contained all ranges of particles. The crushed animal bone concrete gave compressive strength value of 33.27 N/mm2 close or higher to the value of 33.14N/mm2 obtained for concrete sample with crushed coarse aggregate (control).

Table 4.10Results of Compressive Strength for different Concrete Mixes

%age of CAB in concrete	**Compressive strength at 7 days** (N/mm2)	**Compressive strength at 28 days** (N/mm2)
0	22.89	33.14
10	22.98	33.27
25	12.17	19.53
50	10.188	12.21
75	5.91	7.08
100	4.49	5.0

The laboratory test results in compressive strength, seems to indicate that the increase in crushed animal bone aggregate percentage reduces the workability of the mix and also the compressive strength over concrete mixes with CAB. This is due to the fact that CAB aggregates had lighter and less durable and high water absorbing character than CCA. As the design strength of C-25 concrete is 25 N/mm2 and the sample with 10% of replacement gave a value more than that (the control), therefore, we believe the concrete can be used in construction work.

2. unit weight

Table 4.11 unit weight of hardened concrete at 7days &28 days age.

%age of CAB in concrete	Unit weight (KN/m3)	Unit weight (KN/m3)
	7days	**28days**
0	2289.60	2437.25
10	2181.96	2401.96
25	2063.72	2139.22
50	2009.80	1963.24
75	1834.80	1806.37
100	1650.00	1463.23

Lightweight concrete using CAB aggregate can be achieved by replacing crushed coarse aggregate by CAB aggregate approximately 10% or more.

The average unit weights corresponding to 10%, 25%, 50%, 75%,and 100% of CAB aggregate inclusion in concrete are 24.01 KN/m3, 21.39 KN/m3, 19.63 KN/m3, 18.06KN/m3, and 14.63 KN/m3respectively, for nominal concrete mix 1:2.03:2.67.

CHAPTER FIVE

CONCLUSIONS AND RECOMENDATIONS

5.1 Conclusions

Based on the results of this investigation, which have been discussed, the following conclusions are drawn:

The result revealed that the gradation curve of both crushed coarse aggregate and crushed animal bone aggregate were fall within the gradation specifications for ASTM C33/C 33M grading requirements for coarse aggregates designation No. 67 aggregate. In deed the gradations of coarse aggregates affects the workability of fresh concrete; for this case in both coarse aggregates are more smooth and partially smoothed textures were minimized the opportunities of affects the workability of fresh concrete. so it is concluded that the gradations of crushed animal bone aggregate is suitable for use in normal or conventional concrete as a coarse aggregate.

The result revealed that, crushed animal bone aggregate had higher water absorption or less sensitive to poor curing as compared to normal weight concrete especially in the early ages due to the internal water stored by the porous lightweight aggregate and had high value of the Dry Rodded Unit Weight which then results in to achieve a light weight concrete.

According to the result, the lowest slump obtained was 45 mm for the crushed animal bone aggregate mix and the highest slump was 50mm for crushed coarse aggregate mix. Therefore it shows that the workability was getting lower when crushed animal bone aggregate were used in concrete mix due to its high absorption capacity and light in weight than Crushed coarse aggregates and the replacement is by weight, the specific surface area increases as the CAB aggregate content is increased. Since the CAB aggregates are very light and do not settle (sink) easily, slump test is not a true indicator of workability for CAB concrete.

The laboratory test results in compressive strength, seems to indicate that the increase in CAB aggregates in the mix decreases the strength of the concrete. This is due to the fact that CAB aggregates has lower in specific gravity and higher in absorption than crushed coarse aggregates. A previous study [43] has already confirmed similar finding; it is established that lower water content in concrete will result in higher strength. However, compressive strength can be improved by using silica fume (SF).

A Lightweight concrete can be achieved by replacing CAB aggregate approximately 10% or more. This may result in cost minimization due to the decrease in weight of structures such as foundations.

The other and big benefit of using the CAB aggregates is waste reusability and sustainable development for a country.

5.2 Recommendations

The worldwide consumption of coarse aggregate in concrete production is very high, and several developing countries have encountered some difficulties in the supply of this aggregate in order to meet the increasing needs of infrastructural development in recent years, hence the need for research about alternative materials especially waste reusability. The fact that this study concluded the crushed animal bone aggregates are qualified the engineering characteristics test and recommended based from the combined result of the comparison with crushed coarse aggregates; for the use of conventional concrete. But some procedure must be needed proper attentions in order to use crushed coarse aggregates as a coarse aggregate; (i.e. its high water absorption character and low workability which then affects compressive strength of the concrete).

In addition to this using the material needs special attention for cleaning because the impurities may affect compressive strength of concrete but further studies should have to be done on the chemical properties of the material..

As a light weight material it results in a light weight concrete this may reduce the weight of the structure and achieve in economy. But further investigations should be done on this. And here the researcher can say that it can be possible to use this study as a guideline; if the remaining quality tests are completed.

In the meantime, this study was conducted in partial fulfillment of educational requirement: The researcher would like to recommend for important information on using the crushed animal bone aggregates as a coarse aggregate for the conventional concrete in Jimma Zone. Therefore, it is recommended that:

Since it is new ideas using crushed animal bone aggregates as a coarse aggregate for the conventional concrete in Jimma Zone, so the first beneficiaries are the community lived around the study area should be aware of the use of those alternative construction materials which is existing in the surrounding and with no significant uses in the industrial sectors but causing different problems in the environment. These must need the contributions of concerning bodies (i.e. Local authorities) as well as community participation in the use of the material in accordance with waste minimization.

In order to use crushed animal bone aggregates as a coarse aggregate, due attentions of procedures and methods of selecting the right aggregate must be identified, prior to the trainings given to professionals who are directly involved as well as the local community until sufficient knowledge about the importance and the use of crushed animal bone aggregates as a coarse aggregate is assured.

Although further investigation will be required to study crushed animal bone aggregates technological mechanism in producing aggregate with good engineering characteristics and cost effectiveness achieved in terms of increased strength.

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Appendix: A

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 Trans-potation; test is not highlystandardizedBetween 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	0.2 to 2%	Some researchers have found a general trend of reduced durability for natural

	Text reference(2.1.1)		coarse aggregate in concrete exposed to freezing and thawing with increased absorption.
Porosity	None Text reference(2.1.1)	1 to 10% by volume for coarse aggregate	Porosity - The ratio, usually expressed as a percentage, of the volume of voids in a 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 Text reference(2.1.5.1)	0.01 to 0.20% or more after 6 months	Both fine and coarse aggregate can be tested. Coarse aggregates must be crushed 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

Applicable standard and required specifications for the study

Table 2 the appropriate ASTM, AASHTO, ACI, Ethiopian and British Standards

NO	AGGREGATE PROPERTIES & REQUIREMENTS	STANDARDS	CODE	TYPES OF AGGREGATE	
				Coares aggregate	SAND
				SPECIFICATIONS	
1	*Sieve Analysis; Graduation Requirements % Passing	ASTM	C136, C117,		
		AASHTO	T-11		
		ES	C. D3. 201		
2	Flakiness index % maxim	ASTM	C-33		
		BS	05.1:1989	≤30%	
3	FINENESS MODULUS	ASTM			
		ES	C. D3. 201		2 to 3.5
4	LOOSE UNIT WEIGHT kg/m3	ASTM	C-29	1245 and 1825	1520 – 1680
		AASHTO			
5	Abrasion and Impact in the Los Angeles Machine % maxim	ASTM		25 to 50%	
		AASHTO			
		ES	C. D3. 201	50%	
6	Absorption (moisture contents at SSD)	ASTM	C-127, C-128,	0.2% to 4%	0.2% to 2%,
		AASHTO			
7	Specific Gravity Apparent Specific Gravity Bulk Specific Gravity Bulk Specific Gravity (S.S.D basis)	ASTM	C127, C128,	*2.30 to 2.90	2.30 to 2.90
		AASHTO	T 85, T 84	2.4 to 2.9	2.4 to 2.90
		ES	C. D3. 201	2.4 to 3.0	2.4 to 3.0
8	Free-water contents	ASTM	C70-79, C 127	0.5% to 2%	2% to 6%
9	Surface water contents	ASTM	C70-79, C 128,	1% to 6%.	3% to 8%
		AASHTO	T 255		
10	Bulk density (dry-rodded unit weight) kg/m3	ASTM	C -29	1200 to 1760 kg/m3	1520 – 1680
		AASHTO	T-19		

11	Aggregate Crushing Value (ACV)	ASTM			
		BS	812110:1990	≤ 35%	
12	Aggregate Impact Value (AIV)	ASTM			
		BS	812112:1990	≤ 30%	
13	Sodium soundness	ASTM	C88-90&C33	12% max.	10% max.

Appendix B

QUALITY TEST OF AGGREGATE

1.1 COARSE AGGREGATE

1.1.1 SIEVE ANALYSIS

Table 3: Sieve analysis test result for **CAB** (Trial 1)

Sieve size (mm)	Weight retained(kg)	% retained		% Pass	ASTM Limit C-33-03	
		Individual	Cumulative		lower	Upper
25	0			100.00	100	100
19	297.6	7.29	7.29	92.71	90	100
9.5	2780.8	68.15	75.44	24.56	20	55
4.75	845.58	20.72	96.17	3.83	0	10
2.36	78.45	1.92	98.09	1.91	0	5
0.075	75.4	1.85	99.94	0.06	0	0
Pan	2.56	0.06	100.00	0.00		
Total sample weight	4080.39	100			-	

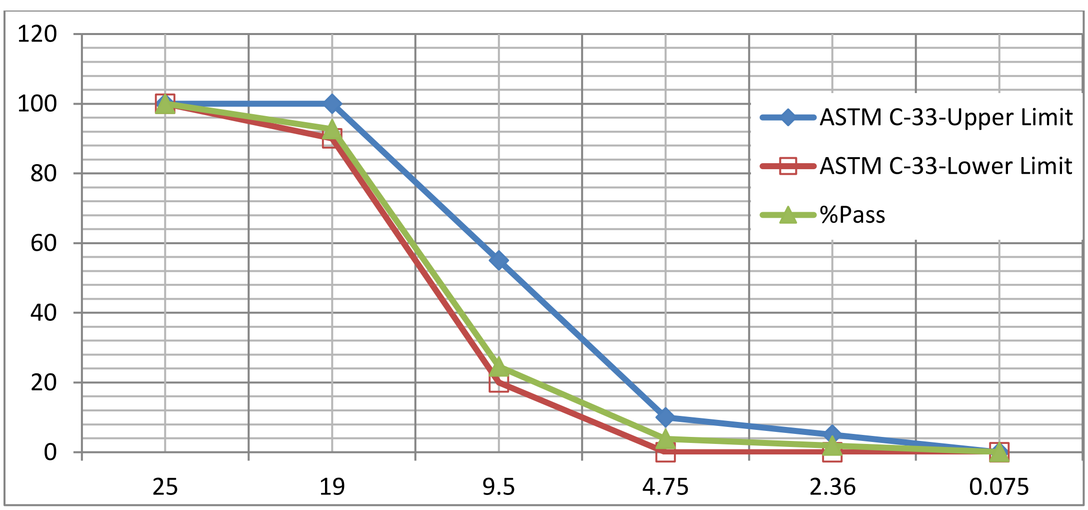

Figure 1: the gradation curve for CAB

Table 4: Sieve analysis test result for CAB (Trial 2)

Sieve size (mm)	Weight retained(kg)	% retained		% Pass	ASTM C-33-03 Limit	
		Individual	Cumulative		lower	Upper
25	0			100.00	100	100
19	299.45	7.61	7.61	92.39	90	100
9.5	2753.8	69.95	77.56	22.44	20	55
4.75	758.1	19.26	96.82	3.18	0	10
2.36	63.4	1.61	98.43	1.57	0	5
0.075	57.6	1.46	99.89	0.11	0	0
Pan	4.32	0.11	100.00	0.00		
Total sample weight	3936.67	100			-	

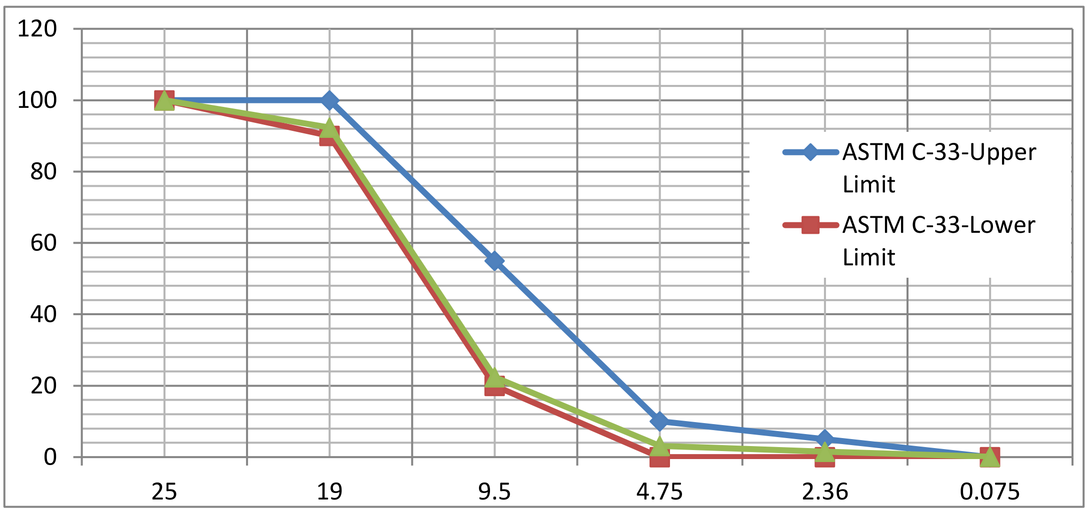

Figure 2: the gradation curve for CA**B**

Table 5: Average Sieve analysis test result for CAB

Aggregate type Size Number (#67)	Sieve size (mm)					
	25	19.0	9.5	4.75	2.36	0.075
CCA	100	92.55	23.52	3.51	1.74	0.09
%Coarser		7.45	76.48	96.49	98.26	99.91
ASTM C-33 upper limits	100	100	55	10	5	0
ASTM C-33 lower limits	100	90	20	0	0	0

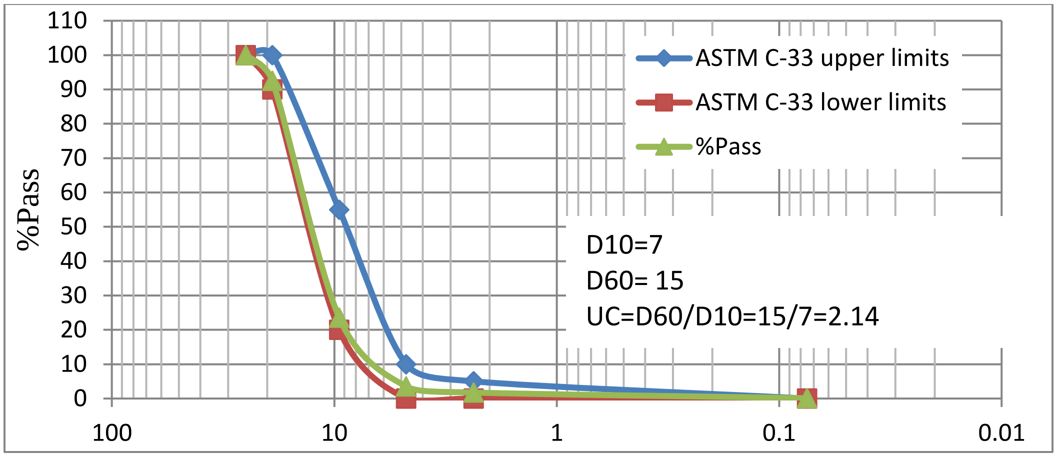

Figure 3 Average gradation curves for CAB

Table 6: Sieve analysis test result for CCA (Trial 1)

Sieve size (mm)	Weight retained(kg)	% retained		% Pass	ASTM C-33-03 Limit	
		Individual	Cumulative		lower	Upper
25	0			100.00	100	100
19	358.74	8.07	8.07	91.93	90	100
9.5	2531.1	56.95	65.02	34.98	20	55
4.75	1231.6	27.71	92.73	7.27	0	10
2.36	254.6	5.73	98.46	1.54	0	5
0.075	67.5	1.52	99.98	0.02	0	0
Pan	0.8	0.02	100	0.00		
Total sample weight	4444.34	100			-	

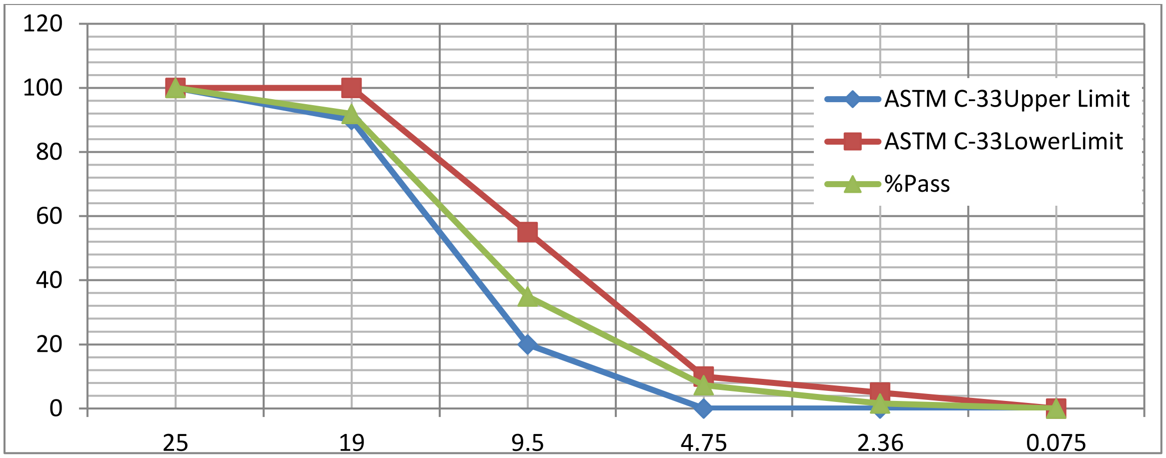

Figure 4 gradation curve for CCA

Table 7: Sieve analysis test result for CCA (Trial 2)

Sieve size (mm)	Weight retained(kg)	% retained		% Pass	ASTM C-33-03 Limit	
		Individual	Cumulative		lower	Upper
25	0			100.00	100	100
19	396.5	8.85	8.85	91.15	90	100
9.5	2546.32	56.83	65.68	34.32	20	55
4.75	1241.6	27.71	93.39	6.61	0	10
2.36	241.26	5.38	98.78	1.22	0	5
0.075	53.2	1.19	99.97	0.03	0	0
Pan	1.5	0.03	100	0.00		
Total sample weight	4480.38	100			-	

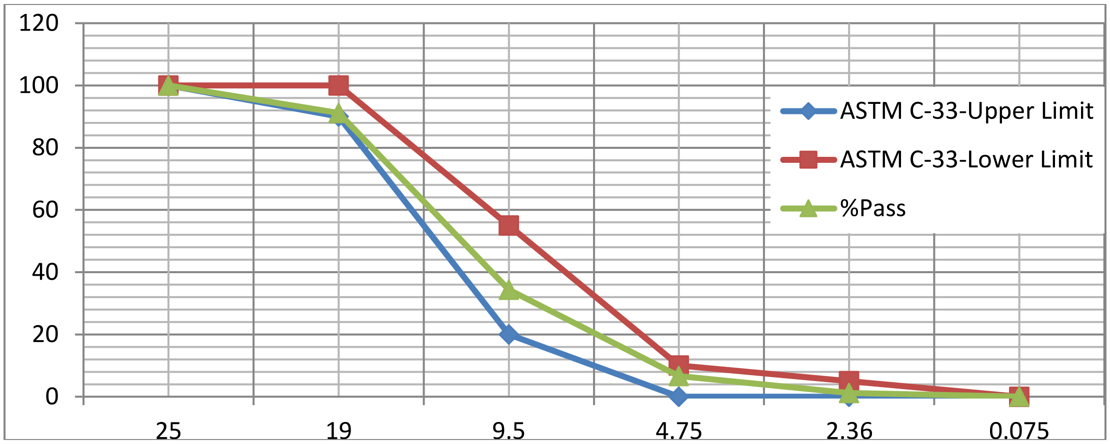

Figure 5 gradation curve for CCA

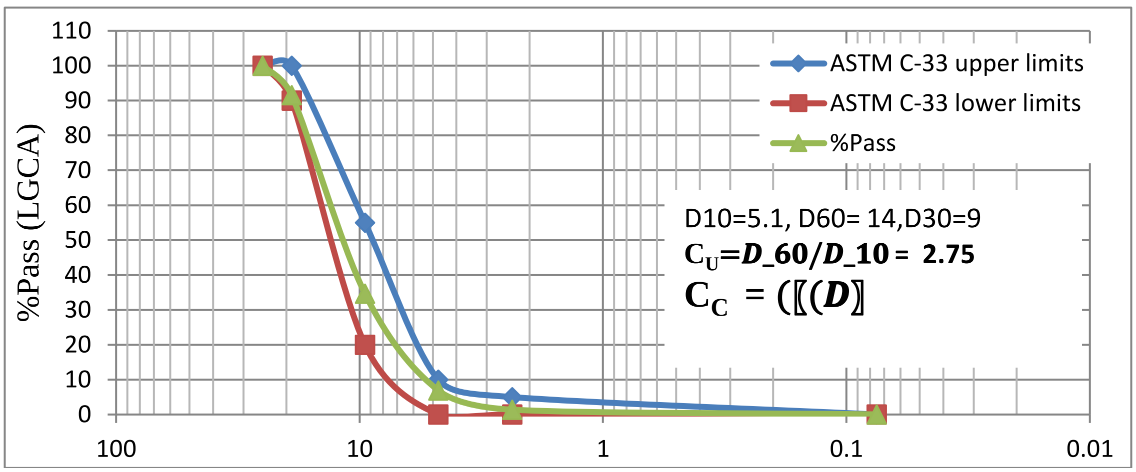

Figure 6 Average gradation curve for CCA

1.1.1 Specific gravity & absorption test of aggregate AASHTO T84/t85

Table 8: specific gravity & absorption test of aggregate

Crushed COARSE AGGREGATE			
Description	Test 1	Test 2	Average
A. Mass of Oven Dry Sample in Air g	1996.2	2011.4	
B. Mass of Saturated Surface Dry Sample in Air g	2026.6	2046.5	
C. Mass Sample in Water g	1246.0	1257	
Absorption	1.02	0.98	1.0
Test temperature ,°C	23 ± 1.7	23 ± 1.7	23 ± 1.7
Apparent Specific Gravity	2.596	2.592	2.6

Bulk Specific Gravity	2.4	2.48	2.44
Bulk Specific Gravity (S.S.D basis)	2.46	2.5	2.48
CRUSHED ANIMAL BONE AGGREGATE			
Description	Test 1	Test 2	Average
A. Mass of Oven Dry Sample in Air g	1975.45	1986.53	
B. Mass of Saturated Surface Dry Sample in Air g	2009.67	2012.45	
C. Mass Sample in Water g	1235.8	1241.9	
Absorption	5.54	2.46	4.0
Test temperature ,^{o}C	23 ± 1.7	23 ± 1.7	23 ± 1.7
Apparent Specific Gravity	2.58	2.42	2.5
Bulk Specific Gravity	2.03	2.71	2.37
Bulk Specific Gravity (S.S.D basis)	2.38	2.44	2.41

1.1.1 UNIT WEIGHT OF AGGREGATES AASHTO T19 ASTM C29

Table 9 UNIT WEIGHT OF CCA

Material type ;	CCA	Date sampled		20/08/2017
Source;	Merkato crushing site	Date tested		24/08/2017
JIT LAB.		Sample no		1
Maximum Size Coarse Aggregate ; 20(19)mm				
Trial No		1	2	Average
Mass of Container (Kg)	A	1.695	1.695	
Mass of Container + Sample (Kg)	B	17.855	16.620	
Mass of Sample (Kg)	B – A	16.16	14.925	
Volume of Container (m3)	C	0.01	0.01	
Unit Weight (Kg/m3)	(B - A) / C	1616	1492	1554.25

Table 4.2.6 UNIT WEIGHT OF CAB

Material type ;	CAB	Date sampled		20/08/2017
Source;	Abboiture houses	Date tested		25/08/2017
		Sample no		2
Maximum Size Coarse Aggregate ; 20(19)mm				
Trial No		1	2	Average

Mass of Container (Kg)	A	1.695	1.695	
Mass of Container + Sample (Kg)	B	8.630	8.525	
Mass of Sample (Kg)	B - A	7.935	7.830	
Volume of Container (m3)	C	0.01	0.01	
Unit Weight (Kg/m3)	(B - A) / C	793.5	783.0	788.25

1. FINE AGGREGATE

1.2 Grain Size Analysis of Fine Aggregate

Table 10: Grain Size Analysis of Fine Aggregate

Trial 1

Grain Size Analysis of Fine Aggregate							
Sieve	Sieve Dia.	Retained	Cumm. Ret	Cumm. Ret	Percentage	Specification limit (%)	
No	(mm)	Wt. (g)	Wt. (g)	(%)	passing	lower	Upper
	9.5	0			100		
4	4.75	68.6	68.6	4.59	95.41	95	100
8	2.36	84.7	153.3	5.66	89.75	80	100
16	1.18	123.1	276.4	8.23	81.53	50	85
30	0.6	362.1	638.5	24.20	57.32	25	60
50	0.3	569.1	1207.6	38.04	19.28	10	30
100	0.15	89.6	1297.2	5.99	13.29	2	10
200	0.075	195.3	1492.5	13.05	0.24	0	5
Pan		3.6	1496.1	0.24		0	0
Total		1496.1		100.00			
FM =					2.797		

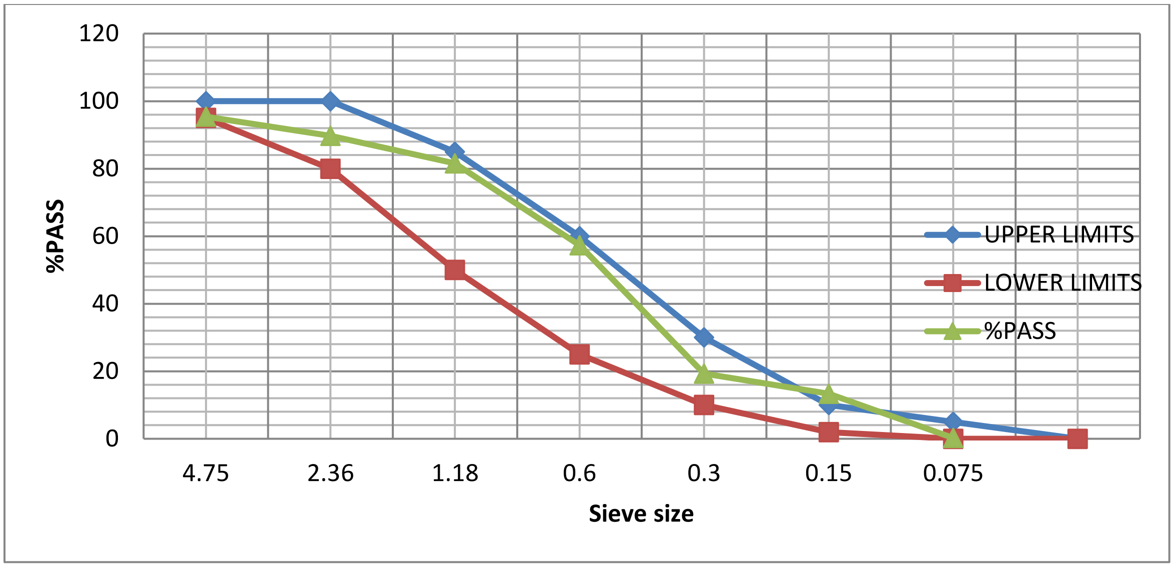

Figure 7 Grain Size Analysis of Fine Aggregate

Table11: Grain Size Analysis of Fine Aggregate for Trial 2

Sieve No	Sieve Dia. (mm)	Retained Wt. (g)	Cumm. Ret Wt. (g)	Cumm. Ret (%)	Percentage passing	Specification limit (%)	
						lower	Upper
	9.5	0			100		
4	4.75	42.3	42.3	2.52	97.48	95	100
8	2.36	56.9	99.2	3.39	94.09	80	100
16	1.18	165.3	264.5	9.85	84.24	50	85
30	0.6	589.2	853.7	35.12	49.12	25	60
50	0.3	365.4	1219.1	21.78	27.34	10	30
100	0.15	347.1	1566.2	20.69	6.65	2	10
200	0.075	85.3	1651.5	5.08	1.57	0	5
Pan		26.3	1677.8	1.57	0.00	0	0
Total		1677.8		100.00			
FM =					2.583		

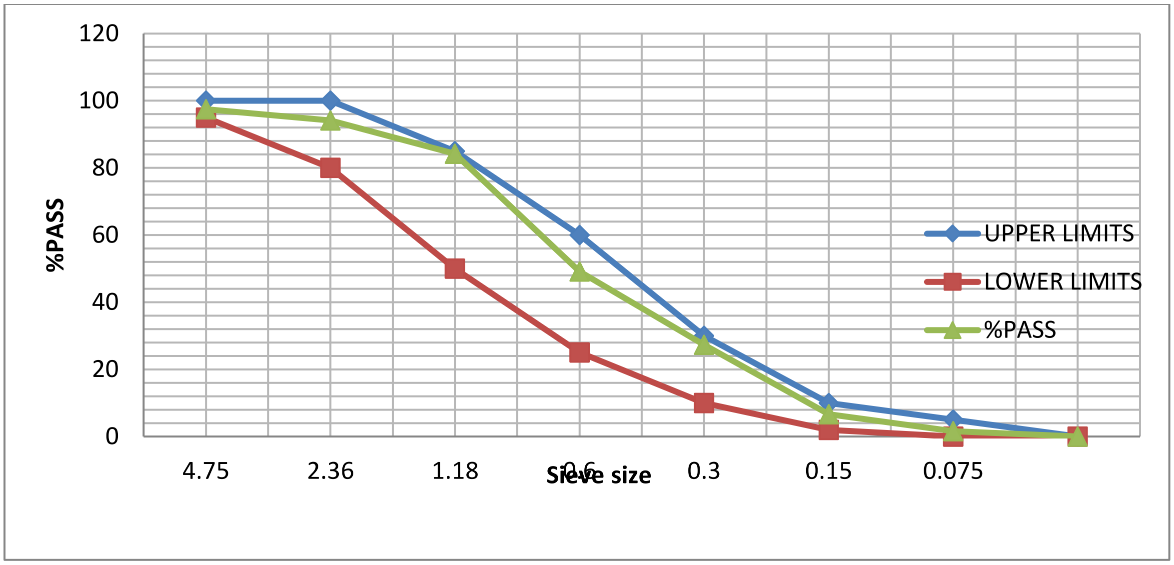

Figure 8 Grain Size Analysis of Fine Aggregate for trial 2

Table 12Grain 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
	9.5	100	lower	upper	
4	4.75	97.48	95	100	Passed
8	2.36	94.09	80	100	Passed
16	1.18	84.24	50	85	Passed
30	0.6	49.12	25	60	Passed
50	0.3	27.34	10	30	Passed
100	0.15	6.65	2	10	Passed
200	0.075	1.57	0	5	Passed
Pan		0.00	0	0	

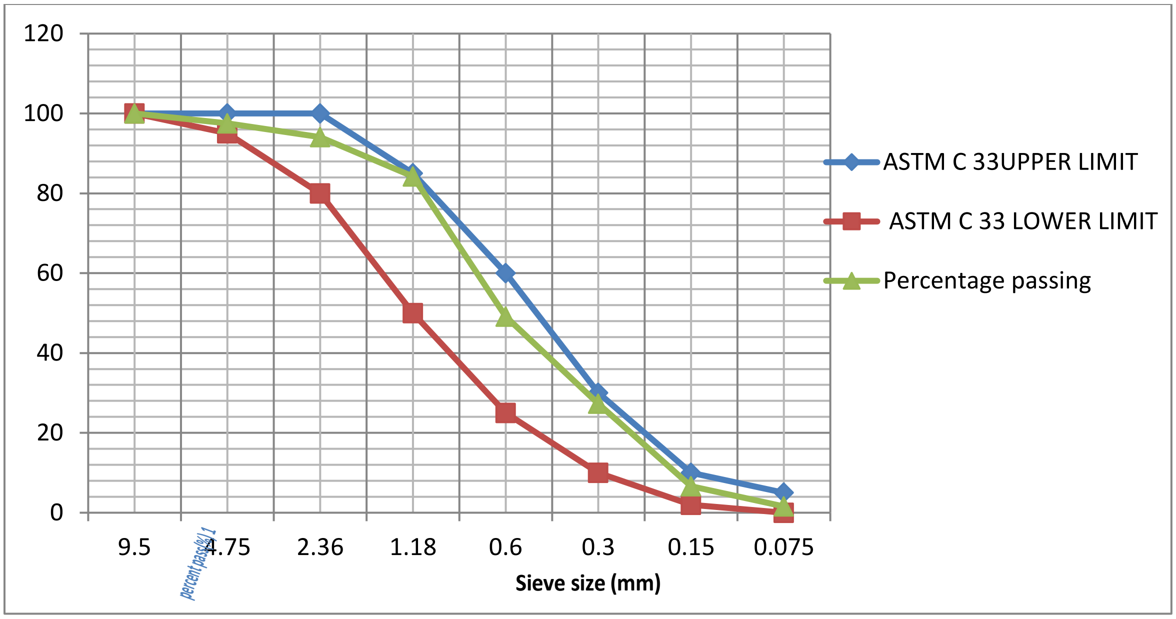

Figure 9 Average Grading Curve Test for Fine Aggregates

The average finess modulus $=\frac{2.797+2.583}{2}= 2.69$

1.3 Specific Gravity & Absorption Test of Aggregate

Table 13: specific gravity & absorption test of aggregate

AASHTO T84/T85			
TEST DATA			
FINE AGGREGATE			
Description	Test 1	Test 2	Average
A. Mass of Oven Dry Sample in Air g	480.9	485.9	
B. Mass of Saturated Surface Dry Sample in Air g	490.2	495.6	
C. Mass of Flask + Water g	672.6	672	
D. Mass of Flask + Water + Sample g	972.5	982.9	
Absorption	0.75	0.73	0.74
Test temperature ,°C	23 ± 1.7	23 ± 1.7	23 ± 1.7
Apparent Specific Gravity	2.657	2.777	2.717
Bulk Specific Gravity	2.527	2.631	2.579
Bulk Specific Gravity (S.S.D basis)	2.576	2.683	2.63

1.3 Unit Weight of Aggregates (AASHTO T19 / ASTM C29)

Table 14: unit weight of aggregates

UNIT WEIGHT OF AGGREGATES AASHTO T19 ASTM C29				
Compacted Density for SSGCA				
Material type ;	Fine aggregate	Date sampled		20/08/2017
Source;	Gambella	Date tested		24/08/2017
Trial No		1	2	Average
Mass of Container (Kg)	A	0.57	0.57	
Mass of Container + Sample (Kg)	B	4.770	4.970	
Mass of Sample (Kg)	B – A	4.2	4.40	
Volume of Container (m3)	C	0.003	0.003	
Unit Weight (Kg/m3)	(B - A) / C	1400	1468.66	1434.33

APPENDIX C

2. CONCRETE TEST

a. Mix Design Procedure Used In This Research as Per ACI 211.1

Table 15 Properties of aggregate samples used for the mix design

Engineering Properties of Aggregate Used in the Study		Crushed coarse aggregate		Standard Specification
		(CAB)	(CCA)	
1	Specific Gravity (SSD)	2.48	2.6	ASTM C 127 2.4-2.9
2	Water Absorption (%) (SSD)	4.0	1.0	ASTM C 127 0.2% to 4%
3	Dry-Rodded Unit Weight (kg/m3)	733.83	1554.25	ASTM C 29M – 97 1200-1750 <1200 N/m3(light weight)

Properties of fine aggregate				
			Standard Specification	
	Unit weight (kg/m3)	1434.33	ASTM C -29	1520 – 1680
	Fineness modulus	2.69	ASTM C 136	2.2-3.1
	Specific gravity	2.63	ASTM C128	2.30 to 2.90
	Absorption, %	0.74	ASTM C128	0.2 to 2
	Free moisture content, %	0.8	ASTM C70-79	2 to 6
	Loose unit weight (Kg/m3)	1323	ASTM C -29	1520 – 1680
	Specific gr. Of Cement (O.P.C)	3.15	ASTM C 150	

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

Crushed Coarse Aggregate (CCA) and crushed animal bone aggregate (CAB.) (Designation of the samples is given in APPENDEX C-1.1)

Step 1 collected data for mix design:-

Fineness modulus of selected fine aggregate =2.69

Unit weight of dry rodded coarse aggregates =1554.25kg/m3

specific gravity of coarse and fine aggregate in saturated surface dry condition is 2.6 and 2.63 respectively

Absorption characteristic of both coarse and fine aggregate is 1.0%and 0.74% respectively

Specific gravity of ordinary Portland cement =3.15

Free surface moisture in sand =0.8%

Step 2 Determination of water to cement ratio

From the strength point of view the estimated water to cement ratio is 0.62 and

From the Exposure condition the estimated water to cement ratio is 0.5

Therefore, adopt water to cement ratio of 0.5.

Step 3 Maximum size of aggregate and workability

Maximum size of coarse aggregate is 20mm.

Slump of concrete is 50mm.

Step 4 Target mean strength calculation

f'cr, = f' c + 8.5

f'cr=25+8.5=33.5MP……..

(ACI318M;Table 5.3.2.2 Appendix C)

Step 5 cement content

For the slump of 50mm and 20mm maximum size of aggregate, the maximum water content is 185kg/m3

cement content =185/0.5=370Kg/m3

<u>Step 6 weight of corse aggregate</u>

From ACI table 11.4 for maximum size of 20mm coarse aggregate and fineness modulus of sand 2.69,

The dry rodded bulk volume of coarse aggregate is 0.63 per unit volume of concrete.

The weight of coarse aggregate = 0.63*1554.25Kg/m3=979.177kg/m3

<u>Step 7 weight of finre Aggregate</u>

From ACI table 11.9 the first estimate of density of fresh concrete for 20mm maximum size of aggregate

and non air entrained concrete =2355kg/m3

Weight of fine Aggregate =2355-(185+370+979.177)=820.823Kg/m3

Table 16 absolute volume of ingredients

Item No	Ingredient	Weight (Kg/m3)	absolute volume (cm3)	
1	Cement	370	$128*10^3$	
2	Water	185	$185*10^3$	
3	Gravel	979.177	$394.829*10^3$	
4	Air		$20*10^3$	

Therefore ,absolute volume of fine aggregate =(1000-717.289)*103=282.711*103

Weight of fine aggregate =282.711*2.63=743.529 Kg/m3

Step 8 proportions

Ingredients	Cement	Sand	Gravel	water
Quantity				
(kg/m3)	370	743.529	979.177	185
Ratio	1	2.0	2.65	0.5
One bag Cement	50 Kg	100Kg	132.5Kg	25Kg

Table 17 quantities of ingredients in kg with their ratios

Step 9 Adjustment for field condition

Fine aggregate has surface moisture of 0.8%.

Weight of fine aggregates =(743.529+0.008*743.529)Kg/m3=749.477Kg/m3

Coarse aggregate absorbs 1% of water.

Weight of coarse aggregate=(979.177+0.01*979.177)Kg/m3= 988.969Kg/m3

Adjust the amount of water based on moisture content

the required mixing water =(185-749.477 (0.008-0.012)- 988.969 (0.013-0.01))Kg/m3

=169.145Kg/m3

Step 10 Final design proportion

Ingredients	Cement	Sand	Gravel	water
Quantity				

(kg/m3)	370	749.477	988.969	169.145
Ratio	1	2.03	2.67	0.5
One bag Cement	50 Kg	101.5Kg	133.5Kg	25Kg

Table 18 the adjusted quantities of ingredients with their ratios

1.2 MECHANICAL PROPERTIES OF HARDENED CONCRETE CUBE COMPRESSION STRENGTH RESULTS

Table 19 **Concrete Mixes with CCA and CAB Aggregate**

%age of CAB in concrete	**Compressive strength at 7 days** (N/mm2)	**Compressive strength at 28 days** (N/mm2)
0	22.89	33.14
10	22.98	33.27
25	12.17	19.53
50	10.188	12.21
75	5.91	7.08
100	4.49	5.0

Appendix D

Aggregate quality test picture

Coarse Aggregates filed sample

Reducing filed sample to test size

Figure 4: Reducing aggregate filed sample to test size

Sieve Analysis; Gradation

Figure 5: Sieve Analysis; Gradation fine aggregate

Specific Gravity (SSD) and Water Absorption test

Figure 6: Specific Gravity (SSD) and Water Absorption test

Dry-Rodded Unit Weight

Fig7. dry rodded unit weight of aggregates

Fresh concrete

Figure 8.Measuring Slump of Fresh Concrete Mix

C. Casting

Figure 9 .Typical 150 mm Cube Mould

Hardened concrete

Figure10. Compression Test Machine and Test Sample