



**HAWASSA UNIVERSITY
INSTITUTE OF TECHNOLOGY
DEPARTMENT OF CIVIL ENGINEERING
POSTGRADUATE PROGRAM IN CONSTRUCTION TECHNOLOGY AND
MANAGEMENT**

**INVESTIGATION ON THE PRODUCTION PROCESS AND QUALITY OF
AGGREGATES AND HOLLOW CONCRETE BLOCK: A CASE STUDY OF GEDEO
ZONE**

**MSc. IN CIVIL ENGINEERING
(SPECIALIZATION: CONSTRUCTION TECHNOLOGY AND MANAGEMENT)
THESIS**

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JUNE, 2019

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**A THESIS SUBMITTED TO HAWASSA UNIVERSITY THE SCHOOL OF CIVIL
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ADVISORS APPROVAL SHEET

This is to certify that the thesis entitled **“Investigation on the Production Process and Quality of Aggregates and Hollow Concrete Block in Gedeo Zone”** submitted in partial fulfillment of the requirements for the degree of **Master’s** with specialization in **Construction Technology and Management**, the graduate program of the **School Of Civil Engineering**, and has been carried out by **Tinsae Mengistu** ID. No. **PGCoTM/046/09**, under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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ABBREVIATIONS

1. ASTM- American Society for Testing and Materials
2. BS- British Standard
3. Cu - Coefficient of Uniformity
4. Cc - Coefficient of Curvature
5. D10 - 10% of the entire particle are smaller
6. D30 - 30% of the entire particle are smaller
7. D60 - 60% of the entire particle are smaller
8. ERA- Ethiopian Road Authority
9. ES - Ethiopian Standard
10. FM – Fineness Modules
11. HCB- Hollow Concrete Block
12. IS- Indian standard

ABSTRACT

In order to produce Aggregates and hollow concrete blocks with good quality which satisfy strength and durability requirements, great care have to be taken for their production starting from ingredient selection to finished product. In addition to this, every production process should follow proper scientific procedures. Considering this, investigation focusing on production process and quality of Aggregates and HCB has been conducted in various Aggregate and HCB production sites located in Gedeo Zone. The research is carried out by observing the production process, collecting information on method of production through interviews and performing different tests in the laboratory to evaluate the quality of the products. Based on the findings, conclusions are drawn and recommendations are forwarded. The findings of the investigation have shown that in most of Aggregate production site process of production is not modern and scientific. From the investigated crushing sites the Wenago and Golla crushing sites follows the best production process and also the quality of aggregates produced also better than the Waleme and the Mechisho crushing sites, especially the grading requirement was not satisfactory and the aggregates are coarser in Waleme and Mechisho Aggreagtes. All fine aggregate sources investigated in this research were natural sand excavated from river bed and the Gidabo and the Gollelicha sands were unsatisfied in grading requirement, Kilkile sand was better grading and also it passes the organic impurity test and the other two did not. Based on their quality C-30 concrete mix was prepared and the compressive strength test was performed. The mix prepared using Wenago aggregate and Kilkile sand achieved 34.85MPa 28th days compressive strength and the other mix prepared using the Waleme aggregate and Gollelicha sand achieved 28.40MPa. In HCB production sites laboratory tests were not conducted for all ingredients used for production of hollow concrete blocks and they use nominal mixing proportion, no mix design is drown based on materials property. The main products in all production sites is class C and it does not fulfill the standard provided in its compressive strength and block density. In addition to this, handling of those ingredients was very poor, and production process also not conducted properly as specified in the recommended standards.

Keywords: Aggregates, Aggregate property, Compressive Strength,

Construction Materials, Hollow Concrete Block, Production Method, Quality

CHAPTER ONE

1. INTRODUCTION

1.1 Introduction

Construction materials that are used in the construction industry should be passed through necessary tests; all specified tests have to be done in the production process. Aggregates and hollow concrete blocks are building materials, these materials require more time, cost and labor force for their production as compared to other construction materials employed for building construction.

Aggregates, both fine and coarse, take about 65-75% by volume of concrete and are important ingredients in concrete production. The parent materials of aggregates are derived mainly from volcanic activity. The dominant rock for coarse aggregate production in Ethiopia is generally basalt while ignimbrite is most commonly used for masonry stone. On the other hand the majority of sand is collected from riverbeds [1]. Aggregate properties significantly affect the workability of plastic concrete and also the durability, strength, thermal properties, and density of hardened concrete[29].The quality of aggregate is considerably important because at least three-quarters of the volume of concrete is occupied by it.

Hollow concrete block is wall and floor making material in the building construction having one or more large holes with the solid material between 50 and 75 percent of the total volume of the block calculated from the overall dimensions [31]. Production process for hollow concrete blocks must be carried out under careful controlling, starting from batching to curing. Hollow concrete block should be produced by proportioning of ingredients based on their property and by providing appropriate mixing time and slump. Curing time must depend on the type of cement used whether (whether it is PPC or OPC) and must be cured sufficiently by considering necessary prevention mechanism from evaporation of water from the surface. [12]

Failure of concrete structures leading to collapse of building has initiated various researches on the quality of construction materials. This failure has resulted into injuries, loss of lives and investments has been largely attributed to use of poor quality concrete ingredients. It is very important to control the quality of the aggregate to be used in concrete making as well as HCB.

The study aims to investigate the production process and quality of HCB and aggregates commonly produced in Gedeo zone specially Dilla town and around. Nowadays in Dilla town there is a lot of civil works take place such as Hotels, Mixed used buildings, Hospital, Hall building etc. in order to perform such infrastructure there should be adequate construction materials available such as cement, coarse and fine aggregate, HCB etc... in a good quality. Most of the contractor's uses various aggregate resources such as the Wenago crushing site, the Waleme crushing site, the Golla crushing site, the Mechisho crushing sites and also various HCB sources.

1.2. Statement of the Problem

In Aggregate as well as HCB productions there are two distinct but equally important activities one is related to material and the other is the related to the process involved in its production. In order to produce good quality of products care has to be taken for both steps. If care is not taken for materials on their quality and handling mechanism, poor quality of products is obtained no matter how the production process is proper [4].

If care not taken for process involved in production, again poor quality of products is obtained even if the materials fulfills the specification. Such wrong processes or improper practices are using excess water during mixing to improve workability, under or over vibration, Insufficient curing... etc.

The normal weight coarse aggregates for the Ethiopian construction sector are produced by both, traditional and modern means. Traditionally coarse aggregate is produced by heating a boulder at a higher temperature and crushing it by a hammer using a manual labor to the required approximate sizes. Aggregates produced using such method are usually flaky and do not satisfy the grading requirements set by standard recommendations [1]. Nevertheless, such aggregates are used for construction in areas where aggregates crushing machine(s) is not available and quality control is not a criteria in the execution of the work.

Hence, due to the processes in the production and the ingredients unsatisfactory quality Aggregates and HCB quality will be affected and using this aggregates and HCB will affect the final concrete structure and other construction product which also may cause building failure. Failures of construction projects results to loose of life and property damages. Therefore the practices used in the production process and quality of construction materials have to be studied.

1.3 Significance of the Study

Since poor quality construction materials like Aggregates and HCB can have numerous negative impacts on different civil engineering structures, so it will be important to investigate their quality and the production process used to produce these materials.

Study the quality of HCB and Aggregates that are produce in Gedeo zone and around Dilla used to minimize its impact on construction industry of the town as well as the nearby towns. The study will be supportive for construction stakeholders in Gedeo zone town specially to take remedial measures to reduce the impacts of the problem. The study will also be helpful for most technical departments such as Housing Development and Construction Bureau (HDCB).

Therefore, this study has significance in order to create clear understanding about the quality of Aggregate and HCB produced in Dilla town and around and also create a better understand about the mechanism and processes used in Gedeo zone and around in order to produce HCB and Aggregate will be a reference material for stakeholders in construction industry in Gedeo zone.

1.4 Objective

1.4.1 General Objective

The general objective of this study is to investigate the production process and quality of Aggregates and HCB in Gedeo zone.

1.4.2 Specific Objectives

The aim of this study will be achieved with the following specific objectives:

- To assess the production process of aggregates.
- To investigate the quality of aggregate produced.
- To assess the production process of HCB.
- To investigate the quality of HCB.

1.5 Scope and Limitation of the Research

The scope of this research addresses the objectives and tries to investigate the quality and production process of HCB and Aggregates in Gedeo zone. The study was targeted only on Gedeo zone and also considers the properties required in the concrete mix design for Aggregates and only compressive strength test, block density and absorption capacity.

The research is limited to HCB and Aggregates not considers other construction materials due to time and cost limitation. The study considered only those aggregate properties regarding to concrete production for aggregate. Those properties such as aggregate impact value, chemical properties...etc needs to be determined to come up with additional point of view.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Aggregate

2.1.1. General

Aggregate is granular material such as sand, gravel, crushed stone and lightweight aggregates that usually occupies approximately 60 to 75% of the volume of concrete. Aggregate properties significantly affect the workability of plastic concrete and also the durability, strength, thermal properties, and density of hardened concrete. The quality of aggregate is considerably important because at least three-quarters of the volume of concrete is occupied by it [6]. This indicates that it is impossible to get good quality concrete without good quality aggregates. Aggregate has both economical and technical advantages in making concrete.

2.1.2. Function of Aggregates

Aggregates have three principal functions.

- a. They provide relatively cheaper filler for cementing material;
- b. They provide a mass of particles that resist the actions of applied loads and weather, abrasion, percolation of moisture; and
- c. They reduce the volume changes resulting from the setting and hardening process and from moisture changes in the cement-water paste [28].

2.1.3. Classification of Aggregates

- **Size**: - Coarse Aggregates & Fine Aggregates.
- **Specific Gravity**: - Light Weight, Normal Weight and Heavy Weight Aggregates.
- **Availability**: - Natural Gravel and Crushed Aggregates.
- **Shape**: - Round, Cubical, Angular, Elongated and Flaky Aggregates.
- **Texture**: - Smooth, Granular, Crystalline, honeycombed and Porous [5].

Aggregates are classified in different ways based on the source, weight, size and/or mode of production. However, the method of classification widely used in concrete works is based on the aggregate size. Aggregates bigger than 4.75 mm diameters are classified as coarse aggregate and those smaller than 4.75 mm in diameter are classified as fine aggregates.

Aggregates can be classified as natural or artificial depending on their sources. Natural aggregates are obtained from quarries by processing crushed rocks or from riverbeds while

artificial aggregates are obtained from industrial by products such as blast furnace slag. Natural aggregates are most commonly obtained and are relevant for Ethiopian construction sector since artificial aggregates are hardly produced in the country [2].

2.1.4. Origin of Aggregates

It is an accepted fact that the physical and mechanical properties of aggregates are inherited from parent materials, while the properties of the parent material intern depend on its geological formation. Geologically rocks are classified into three major divisions based on their origin, namely Igneous, Sedimentary and Metamorphic [1].

➤ **Igneous Rocks**

Igneous rocks are rocks formed from the solidification of molten matter (magma) either at or below the earth's surface. Igneous rocks are divided into two: plutonic or intrusive, those having cooled slowly within the earth (e.g. granite, diorite, gabro, etc) and volcanic or extrusive, those which are formed from quick cooled lava (e.g. volcanic rock, volcanic glass, felsites, basalt, etc). Plutonic rocks usually have grain sizes larger than 1mm and classified as course or medium grained while volcanic rocks have grain sizes less than 1mm and are classified as fine-grained. These grains are, however, not visible to the naked eyes.

➤ **Sedimentary Rocks**

Sedimentary rocks are formed as strata as a result of sedimentation from disintegrated products. They are stratified rocks usually laid down under water although they can also be formed by wind and glacial action. The sediments are cemented together or compacted during geologic time with varying degree. Typical examples are sand stone, limestone, and shale.

➤ **Metamorphic Rocks**

Metamorphic rocks are formed from pre-existing igneous, sedimentary or metamorphic rocks by the action of heat or pressure or both. The change may be textural, structural or mineralogical accompanied by changes in chemical composition. Typical examples are marble, meta-quartzite, and slate.

2.1.5. Aggregate Properties

The properties of aggregates can broadly be classified as

- a) Inherited properties: - these properties are inherited by the aggregate from the parent rock, such as chemical and mineral composition, specific gravity, hardness, strength, colour...etc.
- b) Acquired properties: - these properties by aggregate in the process of crushing, such as shape, size, texture and water absorption.

Most properties of aggregate depends on the properties of parent rock e.g. chemical and mineral composition, specific gravity, hardness, strength, physical and chemical stability, color, etc. The shape, size and surface texture which are essential for concrete workability and bond characteristics between the aggregate and cement paste are, however, attributes of the mode of production. It is, therefore, essential to understand the mechanical, physical and chemical properties of aggregate and its modes of production in an effort to produce the required quality of concrete at a minimum price. All properties may have a considerable influence on the quality of fresh or hardened concrete [6].

Aggregate properties can be seen by categorizing in to three such as Mechanical property which includes bond, strength, toughness and hardness, Physical property which includes specific gravity, bulk density, porosity and absorption, moisture content, bulking of sand, soundness and chemical property which includes alkali-silica reaction and alkali carbonate reaction [29].

2.1.5.1. Physical properties

A. Grading

Particle size distribution of an aggregate known as grading and it is determined by percentage of passing on each sieve size. Specifying grading and grading limit of aggregates are very important to maintain uniform quality of concrete from batch to batch with suitable workability and economy because it determine paste requirement for workable mixes [13]. If aggregates doesn't conform grading requirements of ASTM grading limit the concrete may require more paste and liable to segregate during handling and placing [6]. Ethiopian standard specify grading requirements for fine and coarse aggregates as shown in Table 2.1 and 2.2 below.

Table 2.1 Grading requirements for fine aggregate

Sieve size	Percentage passing
9.5 mm	100
4.75 mm	95-100
2.36 mm	80-100
1.18 mm	50-85
600 μm	25-60
300 μm	10-30
150 μm	2-10

Table 2.2 Grading requirements for course aggregate

Nominal size of graded aggregate mm	Percentage Passing through test sieves having square opening						
	75mm	63mm	37mm	19mm	13.2mm	9.5mm	4.75mm
38.5	100		95-100	30-70		10-35	0-5
19.5			100	95-100		25-55	0-10
13.5				100	90-100	40-85	0-10

The portion of an aggregate passing the 4.75 mm (No. 4) sieve and predominantly retained on the 75 μm (No. 200) sieve is called “fine aggregate” or “sand,” and larger aggregate is called “coarse aggregate” [13].

There are several reasons for specifying grading limits and nominal maximum aggregate size, they affect relative aggregate proportions as well as cement and water requirements, workability, pump -ability, economy, porosity, shrinkage, and durability of concrete. Variations in grading can seriously affect the uniformity of concrete from batch to batch. Very fine sands are often uneconomical; very coarse sands and coarse aggregate can produce harsh, unworkable mixtures. In general, aggregates that do not have a large deficiency or excess of any size and give a smooth grading curve will produce the most satisfactory results [28].

i. Coarse-Aggregate Grading

The grading for a given maximum-size coarse aggregate can be varied over a moderate range without appreciable effect on cement and water requirement of a mixture if the proportion of fine aggregate to total aggregate produces concrete of good workability. Mixture proportions should be changed to produce workable concrete if wide variations occur in the coarse-aggregate grading. Since variations are difficult to expect, it is often more economical to maintain uniformity in manufacturing and handling coarse aggregate than to reduce variations in gradation. The maximum size of coarse aggregate used in concrete has a bearing on the economy of concrete. Usually more water and cement is required for small-size aggregates than for large sizes, due to an increase in total aggregate surface area [28].

➤ Maximum Aggregate Size

The maximum size of the coarse aggregate influences the paste requirements of the concrete, and the optimum grading of the coarse aggregate depends on the maximum aggregate size. The maximum size of coarse aggregate is the smallest sieve opening through which the entire sample passes. In practice, it is considered that if only a small amount of aggregate is retained on a sieve, it will not significantly affect the properties of the concrete. Thus, it is usual to use a nominal maximum size, which is the smallest sieve opening through which the entire sample is permitted to pass, but need not do so. A percentage (usually 5-10%) of the sample weight may be retained on this sieve.

ASTM grading requirements are based on nominal maximum size. The largest maximum size of aggregate practicable to handle under a given set of conditions should be used. Using the largest possible maximum size will result in: Reduction of cement content, Reduction in water requirement and Reduction of drying shrinkage [28].

ii. Fine-Aggregate Grading

The most desirable fine-aggregate grading depends on the type of work, the fruitfulness of the mixture, and the maximum size of coarse aggregate. In leaner mixtures, or when small-size coarse aggregates are used, a grading that approaches the maximum recommended percentage passing each sieve is desirable for workability. Fine aggregate grading has a greater effect on workability of concrete than coarse aggregates [30].

In BS 882:1992 considers four grading zones; the division into zones is based primarily on the percentage passing the 600µm sieve .The main reason for this is that a large number of sands divide themselves naturally at just that size, grading above and below being approximately uniform. Furthermore, the content of particles finer than the 600 µm sieve has considerable influence on the workability of the mix and provides a fairly reliable index of the overall specific surface of the sand [30].

Table 2.3 shows the grading requirement of BS and ASTM for fine aggregate. BS 882 divides the grading in to four zones, zone 1 is coarser and zone 4 is finer. Grading zone 2 and 3 is moderate grading zones and approach to ASTM standard.

Table 2.3: BS and ASTM grading requirement for fine aggregate

		Percentage by weight passing sieves					ASTM Standard C33-78
		BS 882:1992					
BS	ASTM No.	Grading Zone 1	Grading Zone 2	Grading Zone 3	Grading Zone 4		
9.5mm	3/4 in	100	100	100	100	100	
4.75mm	3/16in	90-100	90-100	90-100	95-100	95-100	
2.36mm	8	60-95	75-100	85-100	95-100	80-100	
1.18mm	16	30-70	55-90	75-100	90-100	50-85	
600 µm	30	15-34	35-59	60-79	80-100	25-60	
300 µm	50	5-20	8-30	12-40	15-50	10-30	
150 µm	100	0-10	0-10	0-10	0-15	2-10	

➤ **Fineness Modulus**

Using the sieve analysis results, a numerical index called the fineness modulus (FM) is often computed. The FM is the sum of the total percentages coarser than each of a specified series of sieves, divided by 100.

$$\text{Fineness modulus} = \frac{\sum (\text{cum. of } \% \text{ retain})}{100} \dots\dots\dots \text{Equation.2.1}$$

The specified sieves are 75.0, 37.5, 19.0, and 9.5 mm (3, 1.5, 3/4, and 3/8 in.) and 4.75 mm, 2.36 mm, 1.18 mm, 600µm, 300 µm, and 150 µm (No. 4, 8, 16, 30, 50, and 100).

Note that the lower limit of the specified series of sieves is the 150 µm (No. 100) sieve and that the actual size of the openings in each larger sieve is twice that of the sieve below. The

coarser aggregate size, the higher the FM. for fine aggregate used in concrete, the FM generally ranges from 2.0 to 3.3 as per defined ACI E-701[13] and According to Ethiopian Standards ES C. D3. 201, the fineness modulus of fine aggregate is in the range of 2.0-3.5 with tolerance of ± 0.2 . It is used as an index to the fineness or coarseness and uniformity of aggregate supplied, but it is not an indication of grading since there could be an infinite number of grading which will produce a given fineness modulus. The following limits may be taken as guidance [17].

Table 2.4: limitation of fineness modulus as guideline for different sand category

Category of sand	Fineness modulus(FM) limit of sand
Fine sand	2.2-2.6
Medium sand	2.6-2.9
Coarse sand	2.9-3.2

Sand having a fineness modulus more than 3.2 will be unsuitable for making satisfactory concrete [17]. However, it is clear that one parameter, the average, cannot be representative of a distribution: thus the same fineness modulus can represent an infinite number of totally different size distributions or grading curves. Therefore, the fineness modulus cannot be used as a description of a grading of an aggregate but it is valuable for measuring slight variations in the aggregate from the same source that is as a day to day check [30].

➤ **Distribution of grain or particle sizes**

Many of the properties of a concrete mix depend on the distribution of grain or particle sizes within the stock aggregate. This is determined by subjecting a representative sample of the material to a sieve analysis using a standard set of sieve sizes, determining the cumulative percent of the sample that passes respectively smaller sieve openings and then plotting the percent passing versus grain size on a logarithmic scale. Grading of granular material will generally vary depending on the processes that produced it. A concrete aggregate grading can fall within one of three nominal classifications. These are described below.

- a. **Uniform:** Aggregate consists of predominantly one particle size;
- b. **Continuous (well graded):** Aggregate contains particles across a wide range of sizes.
- c. **Gap:** Aggregate is deficient in one or more of the intermediate particle sizes.

Gap graded aggregates have been found to create micro structural defects in the concrete as a result of internal bleeding and segregation. Continuously graded aggregates with particles of all sizes may experience particle interference and a high degree of friction which may compromise workability. This is more prevalent in aggregates with poor shape such as crushed aggregates. Sometimes it is beneficial to use gap graded aggregates formed through combining a continuously graded fine aggregate with a nominally single sized coarse aggregate. Here the gap, which lies between the fine and coarse aggregate constituents, serves to reduce friction and particle interference [5].

These nominal aggregate grading's are represented schematically in Figure 2.1 and Figure 2.2 gives representative grading curves for each. In practice either gap or continuously graded aggregates are used. Which of the two is employed depends on the local practice which in turn usually depends on what is locally available [5].

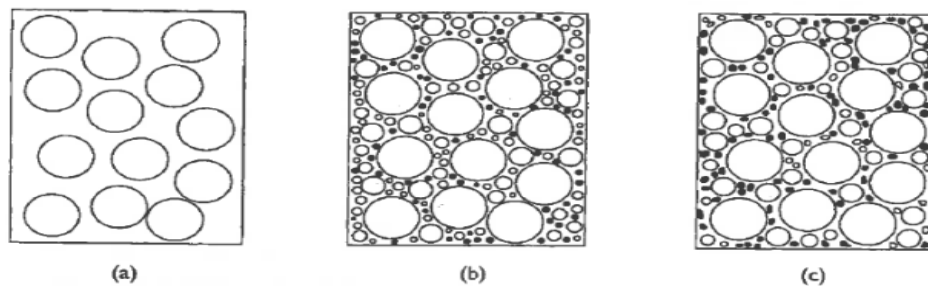


Figure 2.1 Schematic of (a) uniform grading, (b) continuous grading and (c) gap grading of Concrete aggregate [5]

Table 2.5: Unified Soil Classification System (USCS) Criteria

Criterion	Material	
	Gravel	Sand
Uniformity	$C_u > 4$	$C_u \geq 6$
Curvature	$1 < C_c < 3$	$1 < C_c < 3$

Table 2.6: Sand Quality Criteria

Features of test	Interpretation	Range of Value
Co-efficient of Curvature(Cc)	Well graded	1-3
Co-efficient of Uniformity(Cu)	(a)Well graded	>5
	(b)Uniformity graded	1-5
	(c) poorly graded	<1
Zoning using sieve of 0.6mm	Zone-1: Coarse sand	(15-34)%
	Zone-2: Medium sand	(35-50)%
	Zone-3: Medium to fine sand	(60-79)%
	Zone-4: Fine sand	(80-100)%

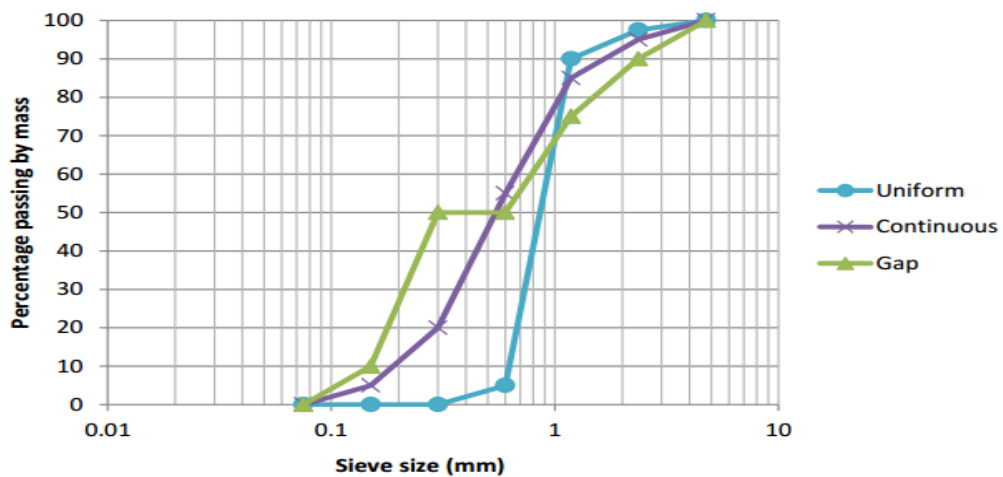


Figure 2-1: Gradation curve for uniform, continuous and gap graded of Sands

The use of larger maximum size of aggregate affects the strength in several ways.

- First, since larger aggregates have less specific surface area and the aggregate–paste bond strength is less; aggregate fails along surfaces of aggregates resulting in reduced compressive strength of concrete.
- Secondly for a given volume of concrete, using larger aggregate results in a smaller volume of paste, thereby providing more restraint to volume changes of the paste. This may induce additional stresses in the paste, creating micro cracks prior to application of load, which may be a critical factor in very high strength concretes [5].

Therefore, it is the general consensus that smaller size aggregates should be used to produce higher strength concrete.

B. Shape and Texture

Particle shape and surface texture influence the properties of freshly mixed concrete more than the properties of hardened concrete. Rough-textured, angular, and elongated particles require more water to produce workable concrete than smooth, rounded and compact aggregate. Consequently, the cement content must also be increased to maintain the water-cement ratio. Hence, aggregate should be relatively free of flat and elongated or at least limited to about 15% by mass of the total aggregate particles because such aggregate particles require an increase in mixing water and thus may affect the strength of concrete, particularly in flexure, if the water cement ratio is not adjusted [5].

On the other hand, mixing water and cement requirement tend to increase as aggregate void content increases because voids between aggregate particles increase with aggregate angularity this can affect concrete strength and economy. The essential requirement of an aggregate for concrete production is such that it remains stable within the concrete and in the particular environment throughout the design life of the concrete without adversely affecting the performance of concrete in either the fresh or hardened state.

C. Unit weight /Bulk Density

The unit weight or bulk density of an aggregate is the mass or weight of the aggregate required to fill a container of a specified unit volume. The volume referred to here is that occupied by both aggregates and the voids between aggregate particles [28]. The bulk density is used to convert quantities by weight to quantities by volume for batching concrete. It depends upon their packing, the particles shape and size, the grading and the moisture content. For coarse aggregate a higher bulk density is an indication of fewer voids to be filled by sand and cement [18].

➤ Factors Affecting Bulk Density or Unit weight

Bulk density depends on the moisture content of the aggregate. For coarse aggregate, increasing moisture content increases the bulk density; for fine aggregate, however, increasing moisture content beyond the saturated surface-dry condition can decrease the bulk density. This is because thin films of water on the sand particles cause them to stick together so that they are not as easily compacted. The resulting increase in volume decreases the bulk density. Other properties that affect the bulk density of an aggregate include grading, specific gravity, surface texture, shape, and angularity of particles. Angularity increases void content while larger sizes of well-graded aggregate and

improved grading decreases void content. The rodded bulk density of aggregates used for normal weight concrete generally ranges from 1280 to 1920 kg/m³ [13].

D. Specific gravity and bulk density of Aggregates

Specific gravity of aggregates generally is indicative of its quality because aggregates greatly influence the strength and absorption of concrete [4]. A low specific gravity may indicate high porosity and therefore poor durability and low strength because concrete density will greatly depend on specific gravity. On the other hand, bulk density of aggregate is mass or weight of the aggregate required to fill a container of a specified unit volume that occupied by both aggregates and the voids between aggregate particles [2]. It is depends upon their packing, the particles shape and size, the grading and the moisture content. For coarse aggregate a higher bulk density is an indication of fewer voids to be filled by sand and cement

E. Porosity, Absorption and Moisture Content and Bulking of Aggregates

The entrapped air bubbles in the rocks during their formation lead to minute holes or cavities known as pores [24]. Due to those pores and higher proportion of aggregate, concrete becomes permeable and ultimately affects the bond between aggregate and cement paste, resistance to freezing and thawing of concrete and resistance to abrasion of aggregate.

The porous aggregate absorb more moisture, resulting in loss of workability of concrete at a much faster rate. Since aggregates contain same porosity, water can absorbed in to the body of the particles. Also water can be retained on the surface of the particle as a film of moisture. Thus stockpiled aggregates can have variable moisture content. It is necessary to have information about the moisture content, since if there is a tendency for the aggregates to absorb water, it will be added to the paste and w/c ratio of the concrete will be higher than desired.

There are four moisture states the only two, the OD (over-dry) and SSD (saturated surface dry) states, corresponds to moisture contents, and either those states used as reference states for calculating moisture contents, the AD (air - dry) and wet states represent the variable moisture contents that will exist in stockpiled aggregates [28].

Stock piling of coarse aggregate is generally, in AD state with effective absorption of less than 1 % , However, fine aggregate is often in wet state, with a surface moisture typically in the range of 2 to 6 % [2].

2.1.5.2. Chemical Properties

A. Alkali-Aggregate Reactions

Alkali-aggregate reactions are chemical reactions in concrete involving certain active mineral constituents often present in some aggregates and the sodium and potassium alkali hydroxides from Portland cement paste. The reactions are potentially harmful only when they produce significant expansion and hence cracking of concrete, leading to loss of strength and elastic modulus. Alkali-aggregate reactions occur in two forms: alkali-silica reaction (ASR) and alkali carbonate reaction (ACR) [1].

Alkali-silica reaction is the reaction between the alkali hydroxide in Portland cement and certain siliceous rocks and minerals present in the aggregates, such as opal, chert and chalcedony. The products of this reaction often result in significant expansion and cracking of the concrete and ultimately, failure of the concrete structure.

Alkali-carbonate reaction on the other hand is the reaction between the cement hydroxides and certain dolomitic limestone aggregates which can also result in deleterious expansion. Alkali-silica reaction is of more concern than alkali-carbonate reaction because the occurrence of aggregates containing reactive silica minerals is more common. Alkali reactive carbonate aggregates have a specific composition whose occurrence is relatively rare. Since the occurrence of dolomitic limestone is very rare in Ethiopia, more emphasis should be given to alkali-silica reactions [1].

B. Deleterious Substances

There are three broad categories of deleterious substances that may be found in aggregates: impurities which interfere with the processes of hydration of cement, coatings preventing the development of good bond between aggregate and cement paste, and certain individual particles which are weak or unsound in themselves. These harmful effects are distinct from those due to the development of chemical reactions between the aggregate and the cement paste. Aggregates may also contain sulphate or chloride salts that can be easily removed by washing in fresh water as otherwise it can have dangerous consequences in reinforced concrete structures resulting in corrosion of steel [1]. Harmful substances that may be

present in aggregates include organic impurities in the form of peat, humus, and organic loam may not be as detrimental but it should be avoided because it causes delay in setting and hardening of concrete, may reduce strength gain, Materials finer than the 75- μm (No. 200) sieve specially silt and clay, shale, coal, lignite, and certain lightweight and soft particles may form a coating on the aggregate particle and may weaken the bond between cement paste and aggregate. The amount of deleterious substance for coarse and fine aggregates according to Ethiopian standard [19] is listed in Table 2.7 and 2.8 below.

Table 2.7 Permissible limits for deleterious substances in fine aggregates

deleterious substances	Maximum percent by mass
Friable particles Clay	1.0
fine silt (passing 63 μm sieve)	3.0
Concrete subject to abrasion	5.0
All other concrete coal and lignite	1.0

Table 2.8 Permissible limits for deleterious substances in coarse aggregates

deleterious substances	Maximum percent by mass
Friable soft fragments	3.0
coal lumps	0.25
Materials finer than 63 μm sieve	1.0
including crusher dust	1.5

2.1.5.3. Mechanical Properties

A. Strength and Hardness

Aggregates contribute the significant proportion of strength possessed by concrete due to their higher modulus of elasticity as compared to the cement paste [4]. To have a strong concrete, the aggregate should have high load bearing capacity and resistant to wearing and abrasion effects. To assess the strength of aggregates, a number of strength tests are undertaken in laboratories. Some of these are; aggregate crushing value, aggregate impact value, Los Angeles abrasion test, ten percent fines values etc. The hardness of the minerals that make up the aggregate particles and the firmness with which the individual grains are cemented or interlocked control the resistance of the aggregate to abrasion and degradation. Soft aggregate particles are composed of minerals with a low degree of

hardness. Weak particles have poor cementation. Neither type is acceptable because of reduction in concrete strength [18].

B. Soundness of Aggregate

The soundness of aggregates is the ability of aggregates to resist excessive changes in volume due to changes in environmental conditions such as freezing and thawing, thermal changes and alternating wetting and drying. The aggregate is said to be unsound when the volume changes result in the deterioration of the concrete. This may appear in the form of local scaling to extensive surface cracking or to disintegration over a considerable depth [24].

2.1.6. Aggregate for Concrete

Aggregate is granular material such as sand, gravel, crushed stone, blast-furnace slag, and lightweight aggregates that usually occupies approximately 60 to 75% of the volume of concrete. Aggregate properties significantly affect the workability of plastic concrete and also the durability, strength, thermal properties, and density of hardened concrete. Furthermore the quality of aggregate is considerably important because at least three-quarters of the volume of concrete is occupied by it [30]. This indicates that, aggregate quality is important to get good quality concrete and it has both economic and technical advantages in making concrete.

There are two main reasons for increasing the amount of aggregates in concrete. The first is that cement is more expensive than aggregate, so using more aggregate reduces the cost of producing concrete. The second is that most of the durability problems, e.g. shrinkage and freezing and thawing, of hardened concrete are caused by cement. Generally, concrete shrinkage increases with increase in cement content; aggregates, on the other hand, reduce shrinkage and provide more volume stability.

In choosing aggregate for use in a particular concrete, attention should be given among other things to three important requirements [17].

1. Workability, when fresh for which the size and gradation of the aggregate should be such that unnecessary labor in mixing and placing will not be required.
2. Strength and durability when hardened for which the aggregate should be:
 - i. Be stronger than the required concrete strength.
 - ii. Contain no impurities which adversely affect strength and durability.
 - iii. Not go in to undesirable reaction with the cement.

- iv. Be resistant to weathering action.
3. Economy of the mixture –meaning to say that the aggregate should be:
- i. Available from local and easily accessible deposit or quarry
 - ii. Well graded in order to minimize paste hence cement requirement

2.1.7. Compressive Strength of Concrete

The strength of a material is defined as the capability of the material to resist stress without failure. The strength of hardened concrete is fundamental in structural design, and is widely used as an index to predict other concrete properties [15].

The compressive strength of concrete is one of the most important and useful properties of concrete. The primary purpose for design concrete is to resist compressive strength in structural members, in general is the characteristic material value for classification of concrete.

In addition to this, Strength is usually the basis for acceptance or rejection of the concrete in the structure. The specifications or code designate the strength (nearly always compressive) required of the concrete in the several parts of the structure. Because concrete is an excellent material for resisting compressive loading, it is used in dams, foundations , columns, arches and tunnel linings where the principal loading is in compression.

Strength is most of the time determined by means of test either cylinders and cubic test made of fresh concrete on the job and tested in compression at various ages. The requirement is certain strength at an age of 28 days or such earlier age as the concrete is to receive its full service load or maximum stress. Therefore, it is important to this work that the effect fines aggregate or sand have on the strength of concrete been investigated.

2.1.8. Aggregates of Production

2.1.8.1. Coarse aggregate production

The quality of aggregates determines not only the strength of concrete but also the durability and structural performances of concrete. The natural aggregates are formed as a result of the processes of weathering and abrasion or through crushing a large parent mass. This shows that the properties of aggregates depend on the properties of the parent rock [4].

The production of crushed stone aggregate involves several processes, such as

- Extraction (Stripping, Drilling and blasting, Loading and, Transporting)
- Crushing (Primary crushing, Secondary crushing and tertiary crushing)
- Screening and
- Product handling

Excavating crushed stone, sand and gravel depends on the geological characteristics, and the extent and thickness of the deposit. Quarrying and mining stones require drilling and blasting. Then, it can be extracted by using shovels, bulldozers. Processing of quarried rock and large gravel requires crushing, which depends on the size of the final product. After crushing, the aggregate is moved by conveyors to bins or is stockpiled by size. Finally, the aggregate is loaded on trucks, railcars, barges or freighters [5].

2.1.8.2. Coarse Aggregate Production In Ethiopia

The two dominantly produced aggregates, lightweight (namely pumice and scoria) and the normal weight (basalt), do have different modes of productions. The lightweight aggregate is produced from quarries by simple digging or bulldozing as it is a soft material and the different sizes produced mainly depend on digging or bull dozing. The normal weight coarse aggregates for the Ethiopian construction sector are produced by both, traditional and modern means [1].

Traditionally coarse aggregate is produced by heating a boulder at a higher temperature and crushing it by a hammer using a manual labor to the required approximate sizes. Aggregates produced using such method are usually flaky and do not satisfy the grading requirements set by standard recommendations. Nevertheless, such aggregates are used for construction in areas where aggregates crushing machine(s) is not available and quality control is not a criteria in the execution of the work [1]. On the other hand, the modern way of aggregate production requires aggregate crushing machines so that the quarry is either drilled, blasted or dug with special mechanisms, fed to crushers, crushed, sieved and separated according to their sizes. The different sizes commonly known as 01, 02, 03 and 04 are stockpiled separately. Size 02 means aggregates having a maximum aggregate size of 20mm, while 01, 03, 04 has a maximum aggregate size of 10, 30 and 40 mm respectively. This method enables to classify aggregates based on their maximum aggregate sizes and enable engineers to suggest unique mix proportion to arrive at the required concrete quality production. The dust content over the surface of the aggregate,

however, is not given adequate emphasis by the producers while creating serious problems during concrete production. Besides, no attempt has been made, so far, to rehabilitate quarry sites after the mining operation is completed. Not even the old mining sites are systematically recorded and marked properly [1].

2.1.8.3. Fine aggregate production

Sand plays a critical role as a construction aggregate and deserves special attention when considering the means of process control. Unlike coarse aggregate where various types of crushers may be used to upgrade mineral quality, sand basically relies on the same techniques to address both mineral quality and sizing. These techniques are called particle exclusion. Whichever size the Producer decides to eliminate for quality reasons, obviously also affects the sizing [4].

➤ **Natural Sand**

Good quality natural sand is readily available in many areas and may be easy to obtain and process. As with the gravels that they often accompany, the sand deposits may not have been laid uniformly, meaning a potential change in quality and size is possible. In some deposits, sand found below the water table differs in fines content and quality from that found above the water table. Subsurface drilling, sampling, and testing are necessary to know to what degree and where these differences occur. Standard operating procedures in the Quality Control Plan should address the process if differences in size and quality are encountered, as a uniformly graded product of predictable quality is required to be maintained

➤ **Manufactured Sand**

Because of the angularity, manufactured sand is very beneficial for use in hot mix asphalt where stability is critical. For some uses, particle shape is important. Particle shape is set primarily by the crushing operation for the coarse aggregate. Any changes in crushers or crushing techniques may affect the properties of the manufactured sand product and therefore affect the customer's use of the product.

Very few sand products are produced by air classification or by direct non-washed screening. Most sands are produced with wash water and water classification. The key to all rinsing and water classifying systems is adequate delivery of water. Inadequate water

supply and poor maintenance are the two most common reasons for inconsistent sand gradations.

2.1.8.4. Fine Aggregate Production in Ethiopia

Fine aggregates (sand), is unconsolidated and highly variable mixtures of different constituents. The construction industry utilizes sand mainly from streambeds, which are commonly derived from quartzo-feldspathic basement rocks, sandy marine sediments and alluvial deposits [1]. The method of quarrying sand is generally very old and the producers do not attempt to clean and grade the sand right from the source. Typical method of sand quarrying operations and transporting to the nearby loading station is using labors or animal.

2.1.9. Handling and storing of aggregates

Aggregates should be handled and stored in a way that minimizes segregation and degradation and prevents contamination by deleterious substances. Stockpiles should be built up in thin layers of uniform thickness to minimize segregation. The most economical and acceptable method of forming aggregate stockpiles is the truck-dump method, which discharges the loads in a way that keeps them tightly joined. The aggregate is then reclaimed with a front-end loader. The loader should remove slices from the edges of the pile from bottom to top so that every slice will contain a portion of each horizontal layer [4].

Indian standard recommended to stock fine aggregate and coarse aggregate separately on hard dry and level pitch of ground if such surface is not available a platform of planks or old corrugated iron sheets or floor of bricks or thin layer of lean concrete shall be made to prevent the admixture of clay, dust and vegetables or other vegetable matter specially fine aggregates must stocks in a place where loss due to the effect of wind is minimum.

2.2. Hollow Concrete Block

2.2.1. General

Hollow concrete block is an alternative wall and floor making material in the building construction having one or more large holes with the solid material between 50 and 75 percent of the total volume of the block calculated from the overall dimensions [20]. Most hollow concrete blocks have one or more hollow cavity manufactured from a zero-slump mixture of Portland cement (and possibly other cementitious materials), aggregates, water and sometimes admixtures. The use of Hollow concrete block has several advantages:

- they can be made larger than solid blocks, and if lightweight aggregate is used, can be very light, without forfeiting much of their load-bearing capacity;
- they require far less mortar than solid blocks (because of the cavities and less proportion of joints, due to large size), and construction of walls is easier and quicker;
- the voids can be filled with steel bars and concrete, achieving high seismic resistance;
- The cavities can be used as ducts for electrical installation and plumbing.

2.2.2. Types of Hollow Concrete Block

Concrete blocks are produced in a large variety of shapes and sizes, either solid, cellular or hollow, dense or lightweight, air-cured or steam-cured, load bearing or non-load bearing, and can be produced manually or with the help of machines.

Hollow concrete blocks are the most common types of concrete blocks, having one or more holes that are open at both sides. The total void area can more than 50 % of the gross cross-sectional area. The most commonly used HCB are the stretcher blocks with a nominal length of 40 cm (half blocks: 20 cm) nominal height of 20 cm, and nominal widths of 10, 15 and 20 cm.

According to Ethiopian standards hollow concrete blocks shall conform three classes depends on their strength, as Class A, B and C and their requirements are defined below [20].

1. **Class A** used for load bearing wall construction above or below ground level in damp proof course, in exterior walls that may or may not be treated with weather- protective coating and for interior walls and density of Class A

blocks must conform between the range of 900 – 1200 kg/m³ on the other hand Indian standard IS: 2185 (Part I) – 2005 recommended minimum density 1500 kg/m³.

2. **Class B** are used for load bearing wall construction above ground level in damp proof course in exterior walls that are treated with suitable weather- protective coating and their density should be between 900 – 1200 kg/m³ on the other hand Indian standard IS: 2185 (Part I) – 2005 recommended minimum density within the range of 1000-1500 kg/m³ but class C is recommended for non-load bearing wall.
3. **Class C** are used for non-load bearing interior walls and exterior panels walls in steel or reinforced concrete framed construction when protected from weather by rendering or by some other efficient treatment and their density should be between 600 - 900 kg/m³.

Ethiopian standard CES 24- 2013 recommended maximum dimensional variation shall be +5 mm and nominal dimension are listed in the table 2.9 below.

Table 2.9 Nominal dimensions of hollow concrete blocks

Breadth (mm)	Height (mm)	Length (mm)	Face shell (mm)	Web (mm)
100	200	400	20	20
150	200	400	25	25
200	200	400	30	25
250	200	400	35	30
300	200	400	40	30

According to [23] HCB production guidelines, Classes of Hollow Concrete Blocks are

- Load bearing HCB Class A and B
- Non load bearing HCB Class C

Standard Dimensions to ESC.DC.301

- 10 cm x 20 cm x 40 cm (10cm HCB)
- 15 cm x 20 cm x 40 cm (15cm HCB)
- 20 cm x 20 cm x 40 cm (20cm HCB)
- 20 cm x 22 cm x 54 cm (ripped slab block)

2.2.3. Materials for Hollow Concrete Blocks Production

Since the ingredients of concrete can be of very different types and qualities, not only depending on their local availability, but also on the desired properties of block, equipment and production method, it is not possible to give detailed recommendations on materials and mix proportions, other than very general guidelines. It is up to the manufacturer to select the most suitable materials and design of mixes by trial and error, and making tests with the available equipment under the conditions of full-scale production [31].

A. Cement

The following cements are commonly used in concrete block making: Ordinary Portland cement (OPC), special cements such as Portland blast furnace cement, sulfate-resisting Portland cement and others, used where special properties are of importance. Rapid hardening Portland cement (RHPC): more finely ground cement, which hardens much faster than OPC. It is especially useful:

- where storage space is limited,
- when rapid production is important, and
- to produce good strength blocks despite poor gradation of aggregate

B. Aggregates

In order to facilitate transportation, handling and laying concrete blocks, it is necessary to reduce their density. This is achieved by reducing compaction, ensuring a relatively high proportion of air gaps between the aggregate particles and/or using lightweight aggregates. Hence it is important to have a relatively high proportion of coarser particles, because too much fine aggregate would fill the gaps and increase the density. However, a carefully measured amount of very fine particles is necessary to produce the cement paste required to bind the coarser particles.

The maximum particle size of coarser aggregates is 13 mm (or 10 mm for hollow blocks). Rounded stones produce a concrete that flows more easily than angular (broken) particles, but the latter give higher 'green strength' to the newly demolded block, because the particles interlock. This is very important for concrete block production [11].

Aggregates should be pass through a sieve of nominal aperture of 9.5 mm in addition to this the size of aggregate should not exceed two-third of the thickness of the thinnest part of the shell or web unit [12].

C. Water

Water that is fit for drinking is suitable. The quality of water needed for making good Hollow concrete block is very important; it affects the strength and durability of HCB. Hence, it better to use water fit for drinking purpose in the production of HCB.

D. Admixtures

In addition to those ingredients described above, basic components various chemicals, called admixtures, can be used to alter curing time, increase compressive strength, or improve workability sometimes pigments may be added to give the blocks a uniform color throughout.

2.2.4. Production Process of Hollow concrete block

The process of manufacture of concrete hollow blocks involves the following 5 stages;

[12]

- 1) Proportioning
- 2) Mixing
- 3) Molding
- 4) Compacting & placing
- 5) Curing

1. Proportioning

The determination of suitable amounts of raw materials needed to produce concrete of desired quality under given conditions of mixing, placing and curing is known as proportioning.

➤ Aggregate-Cement Ratio

After determining the correct blend of aggregates, the proportion of aggregate to cement must be found by trials with different ratios, e.g. 6:1, 8:1,10:1, up to 16:1 by weight, and testing the qualities of blocks produced. The proportion of fine aggregate to cement is of special importance: if the ratio is too high, the mortar will lack the cohesiveness needed for green strength and will be too weak to impart enough strength to the matured blocks; if the proportion is too low, the mortar will be very cohesive and the mix may not flow easily in handling and filling the mould.

➤ Water-Cement Ratio

Only water that is fit for drinking should be used to mix the concrete. The correct amount of water to be added to the mix depends on the types and mix proportions of aggregates and cement, the required strength of the block, and the production method and equipment used. The concrete must contain just enough water to facilitate production without any slumping of blocks occurring after demolding. If the aggregates are dry, they may absorb some of the water (lightweight aggregates may absorb up to 20 % by weight), but if the aggregates are wet, the blocks will take longer to dry out. As a simple test for cohesiveness, no excess water should be visible when a lump of concrete is squeezed in the hand, but if the sample is rubbed quickly on a smooth round metal bar or tube (2 to 4 cm in diameter) a slight film or paste should be brought to the surface [33].

2. Mixing

Aggregates can be batched by volume or by weight, but the latter is more accurate. For this reason, cement should only be batched by weight, or preferably by using only whole bags of 50 kg. Since concretes begin to set within 30 to 60 minutes, depending on the type of cement and ambient temperature, only so much concrete must be prepared as can be used up before that happens. In hot climates, the fresh mix must be shaded from the sun to avoid premature setting.

In case of hand mixing, it must be done on a level, smooth, hard surface (e.g. concrete slab or steel plate). Because of the relatively low cement content of the concrete and the need for a cohesive mix, thorough mixing is essential. Thus the best mixes are obtained with mechanically operated mixers. The quality of concrete blocks depends largely on the type of mixer and period of mixing. The free fall, revolving drum type mixers are not suitable, because of the semi-dry nature of the mix. Pan mixers have a quick moving action and are thus recommended.

The objective of thorough mixing of aggregates, cement and water is to ensure that the cement-water paste completely covers the surface of the aggregates. All the raw materials including water are collected in a concrete mixer, which is rotated for about 1 ½ minutes. The prepared mix is discharged from the mixer and consumed within 30 minutes [11].

3. Molding

Concrete blocks can be molded by several methods, ranging from manually tamping the concrete in wooden or steel mould boxes to large-scale production with 'egg-laying' mobile machines and fully automatic stationary machines. "Egg-laying" mobile machines are

designed for medium-scale production, either on-site or in a factory. The name was given to these machines, because they leave the blocks to dry where they are produced on a flat production surface and move a short distance away to produce the next batch of blocks, and so on. The quality of blocks generally increases with the degree of mechanization, but medium standards are normally adequate for most construction purposes.

4. Compaction and placing

The purpose of compacting is to fill all air pockets with concrete as a whole without movement of free water through the concrete. Excessive compaction would result in formation of water pockets or layers with higher water content and poor quality of the product. Semi-automatic vibrating table type machines are widely used for making hollow concrete blocks. The machine consists of an automatic vibrating unit, a lever operated up and down metallic mould box and a stripper head contained in a frame work.

In the case of mechanical compaction, the mould shall be filled up to overflow, vibrated or mechanically tamped and struck off level. After remolding the blocks shall be protected against sun and wind by placing on the shade until they are sufficiently hardened to permit handling without damage. On the other hand, [23] specify to vibrate the mixture for 60 second before extruded as hollow concrete block and transported and remains for 24 hours on wooden pallet then it is be cured covered by plastic sheet to enhance the curing process and preventing the water from evaporation.

5. Curing

Curing is one of the most important activities in the production process. The purpose of curing is to replace the evaporating water through sun and/or air. Also the hydration process, a chemical reaction, needs water to set/harden the mortar.

The blocks are either left to set and harden where they were molded, or carried away on pallets to the curing place. In all cases it is important to keep the concrete moist, for example, by regularly spraying with water, until the concrete has obtained sufficient strength.

Concrete blocks on the site shall be cured in water tank or a curing yard by being kept thoroughly moist with water for a period of at least 14 days [26]. When the blocks are cured in an immersion tank, the water of the tank shall be changed at least every 4 days. On the other hand, steam curing can be adopted for the purpose of reduction curing time.

The blocks shall not be used prior to one month after production in order to complete initial shrinkage before blocks are laid in the wall. Recommended 10 days of curing time, in addition to this, date of production must be written on blocks for the purpose of identification whether it is ready or not for construction [23].

2.2.5. Physical requirements

All units shall be sound and free of cracks or other defects which interfere with the proper placing of the unit or damage the strength or performance of the construction. Minor chipping resulting from the customary methods of handling during delivery, shall not be deemed grounds for rejection. Where units are to be used in exposed wall construction, the face or faces that are to be exposed shall be free of chips, cracks, or other imperfections, except that if not more than 5 percent of a batch contains slight cracks or small chippings not larger than 25 mm [11] Or 10mm [20, 25], this shall not be deemed grounds for rejection.

➤ Dimension and Tolerance of Hollow concrete block

Hollow Concrete block, shall be referred to by its nominal dimensions. The term 'nominal' means the standard dimension which designed by manufacturer plus thickness of the mortar joint. For modular size units nominal dimension equal to standard dimension plus 9.53 mm but for non-modular size units it exceeds the standard dimension by 3.18 to 6.35 mm [11]. Other standards such as Indian standards [25] recommended mortar joint 10 mm for modular size and 6 mm for non-modular ones.

According to [11, 12] over all dimensions tolerance (length, width and height) of hollow concrete block shall not differ by more than 3.18 mm from specified standard dimension. In addition to this, face shells and webs thickness shall not less than $\frac{1}{2}$ in or 12.7 mm for non-load bearing hollow concrete block but load bearing shall conform the Table 2.10. In case of Indian standard [25] over all dimensions shall not differ by +5 mm for length and +3 mm for height and breadth in addition to this face shells and webs thickness shall conform the Table 2.11.

On the other hand Ethiopian standard [20] specify maximum dimensional variation (length, height, breadth), it should be + 5mm for nominal dimensions of concrete masonry blocks these are listed below in Table 2.12. In addition to this, face shells and webs

thickness of hollow units shall be at least one-sixth of overall breadth of a unit or 25mm whichever is the greater.

Table 2.10 Minimum face-shell and web thickness

Nominal width (mm)	Face shall thickness (mm)	Web min (mm)
102	19	19
152	25	25
203	32	25

Table 2.11 Minimum face-shell and web thickness

Nominal width (mm)	Face shall thickness (mm)	Web min (mm)
Less than 100 mm	25	25
100 to 150	25	25
150 to 200	30	25

Table 2.12 Nominal dimensions of hollow concrete blocks

Length (l) mm	Breadth (b) mm	Height (h) mm
400	100	200
	150	
	200	
500	100	100
	120	150
	150	200
	200	250
600	100	100
	120	150
	150	200
	200	250

➤ Block Density

For hollow concrete block, low density is probably the most characteristic feature. This is due to the holes. In addition, it depend primary on the aggregate density and the proportions of aggregate because the particle density of individual grading fraction can differ considerably and thus will affect the density of concrete. This property also influenced by the cement, water and air contents [31]

The density of a block can only be obtained after the casting process by taking three blocks taken randomly from the selected samples and then dried to constant mass in a suitable oven heated to approximately 105°C. After cooling the blocks to room temperature, the dimensions of each block shall be measured in centimeters (to the nearest millimeter) and the overall volume computed in cubic centimeters. According to Ethiopian standard [20] and Indian standard [25] three blocks shall be taken for average density and it should conform to the requirements specified in Table 2.13 below. The blocks shall then be weighed in kilograms (to the nearest 10 g) and the density of each block calculated as follows:

$$\text{Density} = \frac{\text{Mass of block in kg}}{\text{Volume of specimen in cm}^3} \times 10^6 \text{ kg/m}^3$$

Table 2.13 density classification of concrete masonry units

Class of HCB	Ethiopian Standard ES 596:2001 (Kg/m³)	Indian Standard IS: 2185-1979 (Kg/m³)
A	900-1200	1500
B	900-1200	1000-1500
C	900-1200	1000-1500

➤ Compressive Strength

The strength of hollow concrete block is closely related to; The specimen size and shape, Method of pore formation, Direction of loading, Age, Water content and Water-cement ratio, Degree of compaction and cement content, Characteristic of its ingredients used, Method of curing, Size and number of holes created.

Both hollow structure of the air holes and mechanical condition of the pore shells have a great influence on the compressive strength of hollow concrete block. It is also been found that a reduction in density due to formation of holes will results in a significant drops in strength. Generally, compressive strength increases linearly with density of structural concrete [31]

The minimum compressive strength at 28 days being the average of six units, and the minimum compressive strength at 28 days of individual units should be tested. Compressive strength of a concrete masonry unit shall be taken as the maximum load in Newton divided by the gross cross sectional area of the unit in square millimeters finally the results of the nearest 0.1 N/mm², separately for each unit and as the average for the six units will be recorded [11].

The following are the minimum compressive strength requirements for blocks at the age of 28 days. The mix proportions of the material components are to be adjusted as required to obtain the required compressive strength according to Ethiopian standard and ASTM standards listed in the Table 2.14 and 2.15 respectively.

Table 2.14 Comprehensive strength of hollow concrete blocks at 28 days

Type of Hollow Concrete Block	Class	Minimum comprehensive strength (N/mm ²)	
		Average of 6 units	Individual units
Load bearing	A	4.2	3.8
	B	4.0	3.2
Non load bearing	C	2.0	1.8

Table 2.14 Comprehensive strength of hollow concrete blocks

Type of Hollow Concrete Block	Class	Minimum comprehensive strength (N/mm ²)	
		Average of 3 units	Individual units
Load bearing	Type N (type I & II)	6.9	5.5
	Type S (type I & II)	4.8	4.1
Non load bearing	(type I & II)	3.5	3.0

➤ Water Absorption

It is a measure of the voids (reachable pore volume) within the net volume of the concrete, including the voids within the aggregate itself. According to [12], the water absorption determined from five full-size units by completely immersed in water at room temperature for 24 hours and they shall be removed from the water and allowed to drain for one minute by placing them on a 10 mm or coarser wire mesh, visible surface water being removed with a damp cloth, and immediately weighed and then all specimens shall be dried in a ventilated oven at 100 °C to 115 °C for not less than 24 hours and until two successive weightings at intervals of 2 hours show an increment of loss not greater than 0.2 percent of the last previously determined mass of the specimen and the recommended Water Absorption requirements of load bearing Hollow concrete block in the table 2.16. On the other hand Ethiopian standard [20] specify water absorption 290 kg/m³ (25%) for load bearing hollow concrete block and 320 kg/m³ (30%) for non-load bearing hollow concrete block but Indian standard recommended 10 percent.

Table 2.16 Absorption requirements of load bearing Hollow concrete block

Grade	Water absorption max (kg/m ³)			
	Oven dry weight Classification (kg/m ³)			
	Light weight		Medium weight	Normal weight
	>1362 (kg/m ³)	1362 – 1682 (kg/m ³)	1682 -2002 (kg/m ³)	< 2002 (kg/m ³)
N-I & II	-	290	240	210
S-I & II	320	-	-	-

➤ Moisture content

Moisture content requirement of concrete block masonry units is related to their linear shrinkage characteristics. Concrete loses or absorbs moisture with changes in the moisture content or relative humidity of the surrounding air. The cement paste may gain moisture and hence “swell”, or lose moisture and “shrink” before it attains an air dry equilibrium condition. It will undergo no dimensional change when the moisture content of the concrete is in equilibrium with the relative humidity of the surrounding so that masonry units are never delivered to a construction site in a saturated condition, and moreover, could not be laid in this condition. If unacceptably moist units are laid in a wall at the time of construction, and this inherent shrinkage is restrained in-service, stresses are developed within the masonry that may cause cracking [11].

2.2.6. Surface texture and finish

Concrete masonry units can be given a variety of surface textures ranging from a very fine close texture to a coarse open texture by the proper selection, grading, and proportioning of aggregates at the time of manufacture.

Textures may also be developed by treating the face of the units while still green by wire brushing or combing, by slightly eroding the surface by playing a fine spray of water upon it, and by splitting (split block) such surface must provide adequate adhesion for plaster or other finish as stated in Ethiopian standard [20]. Colour may be introduced by incorporating non- fading mineral pigments in the facing concrete, or by applying a coloured cement grout or paint to the face of the units soon after they are removed from the moulds. Selected coloured aggregates may also be used in the facing and exposed by washing with water or dilute hydrochloric acid.

2.2.7. Sampling of Hollow Concrete Blocks

The blocks required for carrying out tests in according to Ethiopian standard [20] by taking a sample of 12 hollow concrete blocks shall be taken from every consignment of 10,000 blocks or part thereof of the same size and same batch of manufacture can be taken from stack in which case the required number of blocks shall be taken at random from across the top of the stacks, the sides accessible and from the interior of the stacks by opening trenches from the top and those block shall be kept under cover and protected from extreme conditions of temperature, relative humidity and wind until they are required for test. All the 12 blocks shall be checked for dimensions and inspected for visual defect. Out of the 12 blocks, 3 blocks shall be subjected to the test for block density and water absorption, 6 blocks to the test for compressive strength and the remaining 3 blocks shall be reserved for retest purpose.

On the other hand, Indian standard [25] a sample of 20 blocks shall be taken from every consignment of 5000 blocks. From these samples 20 blocks shall be checked for dimensions and inspected for visual defects Out of the 20 blocks, 3 blocks shall be subjected to the test for block density, 8 blocks to the test for compressive strength, 3 blocks to the test for water absorption and 3 blocks to the test for drying shrinkage and later to the test for moisture movement. The remaining 3 blocks shall be reserved for retest for drying shrinkage and moisture movement if a need arises.

2.3. Gap Identification

The Failure of concrete structures which causes for loose of life and injuries of workers and those who uses these structures and also the general public. Not only these but also it causes for the damage of properties. These all problems may arise from the construction materials quality, so, it invites various researchers. There are different researches conducted in these and related areas but most of them focuses on either in the production process or the quality of one of the materials such as Aggregate or HCB or other construction materials and some of the researches focuses on the improvements by using a replacing materials on concrete or HCB.

Abebe D. (Prof. Dr – Ing.) studied on the need for standardization of Aggregates for concrete production in Ethiopian construction industry. The result confirmed that Aggregate, both fine and coarse, identification, quarrying, storage and handling should be done professionally. In addition, a national wide effort has to be made in preparing mix design procedure, which would enable to arrive at the desired quality concrete production without much difficulty.

Belayneh B. studied on the preparation of Ethiopian standard sand for the purpose of construction and testing. The result confirmed that, Based on grain size analysis and impurity test results it appears that both local sand samples are not comparable with CEN standard sand be used as Ethiopian standard sand as they are taken directly from their natural places.

Tesfaalem K. studied on the effectiveness of quality control for the production of RC and HCB in Addis Abeba housing projects. The result confirmed that Compliance testing for hollow concrete block is insufficient and the results of compressive strength test shows that the products were unsatisfactory.

Therefore, this research investigates focusing on the production processes as well as the qualities of both Aggregate and HCB which both are the widely used construction materials and not produced in factory or in the controlled environment. Investigating the production mechanism is among the main goals of this research because it helps to identify the root cause of less quality products and it also helps to identify where should the improvement requires to improve the quality of the products. Investigating the quality also helps to identify the currently used materials and their compliance of the standards.

CHAPTER THREE

3. MATERIALS AND METHODOLOGY

3.1. General

This chapter gives an overview of the procedures used in carrying out the research study as it pertains to method and instrument of collecting data and also the methods of analysis. To achieve the objective of these research two stages of procedures has been followed. In The first stage, a comprehensive literature review is made to understand the previous efforts, which include the review of textbooks, standards, academic journals, and research papers. In the second stage, Observations on site activities and interviewing the owners, production managers, and workers were made on those production sites, Experimental studies were made on the samples from each production sites, Compare the results with the recommended standards, Based on the findings conclusions are drawn and recommendations are forwarded.

3.2. Study Area

The study area of this research is Gede'o zone. Dilla is the capital town of Gedeo zone, which is one of the ancient towns (around 110 years) which located 360km away from Addis Ababa in southern direction. Its geographical coordinates are approximately 6°24'36"N latitude and 38°18'36"E longitude. The town is found in an area of average altitude of about 5,150ft (1,570 m) above sea level. It is average weather 24°C, Humidity 62% and wind speed 8km/h and the population is around 1.5 million. Dilla is a capital city of Gedeo zone in southern nation nationalities and people region.



Figure 3.1: Administrative map of Gedeo Zone

3.3. Study Design

The study conducted experimentally, to achieve the goal of the research some laboratory tests was conducted using different standards to evaluate the quality of Aggregates and HCB. Experimental design had been used for this study during the study period in order to provide the most reliable proof for the qualities by taking HCB and Aggregate samples produced from different production sites.

3.3.1. Population

The sample frame or target populations of this research for

- Coarse aggregates are the Mechisho site, the Waleme site, the Wenago site, and the Gola site,
- Fine aggregates are the Gidabo site, the Gollecha site and the Kilkile site and
- HCB are Walelign HCB production site, Zemenu HCB and terrazzo production site, Metebaber HCB production site, Hibret HCB production site and Yirgachefe HCB production sites.

3.3.2. Sampling Techniques

The sampling technique that used for this research is a non-probability Sampling technique which is the purposive method. The most used coarse aggregate, sand and hollow concrete blocks available in Gedeo zone was selected based on the information gathered.

3.3.3. Data Collection Process

The data collection processes of this research through

- Observation of the production process,
- Interviewing of skilled and unskilled workers in the production sites and
- Recording the output of each laboratory tests.

3.4. Sources of Data

Both primary data sources and secondary data sources will be used.

- Secondary data needed for this research was collected from different journals, book, website...etc. during the literature review and
- Primary sources of data for this study was laboratory experimental output, the interview and questioner information's.

3.5. Laboratory Procedures

3.5.1. Sample preparation stage

Investigating the quality of Aggregate is the main goal of this research after studying the production process of each site. This investigation is done through performing laboratory works. Hence, sampling the beginning every laboratory investigations; and there should be a careful way of selection of sample that present the actual condition. The sample preparation procedure of aggregate, sand and HCB is discussed below.

Coarse Aggregate and Fine Aggregate

The aim of this research is to investigate the quality aggregates produced and used in the area. After visiting the production site I collect 20–30kg samples of each size for coarse aggregate and 15-20kg fine aggregate available in the site. All the samples I collect had been stored in laboratory storage at normal room temperature as shown in the figure 3.2 below. The investigation was made using the required amount of sample for each test. Before performing the test sample should be prepared using sample splitter in order to have fair distribution of size in the given sample.



Figure 3.2 Samples and Sample Splitter for Sample Preparation

Hollow Concrete Block

Here also the same aim and the same procedure during the visit and the collecting samples from each production sites. I collect 24 HCB of each size available in each production sites and stored in laboratory storage at normal room temperature as shown in the figure 3.3 below.



Figure 3.3 HCB samples from different production sites

3.5.2. Laboratory Tests

- i. Tests on coarse and fine aggregates according to ASTM and BS Standard and Construction Materials Laboratory Manual by professor Abebe Dinku Procedures.
 - Gradation
 - Bulk unit weight
 - Specific gravity
 - Absorption Capacity
 - Free moisture content
 - Fineness modulus
 - Organic Content test (Silt content)
- Tests on HCB according to ASTM and BS Standard and Construction Materials Laboratory Manual by professor Abebe Dinku Procedures.
 - Compressive strength
 - Absorption Capacity
 - Free moisture content
 - Density

3.5.2.1. Coarse Aggregate Tests

➤ Determination of Gradation of Coarse Aggregate

Objective: - This test method covers the determination of particle size distribution or grading by

Procedure:

1. The sieves and the pan were weighed and recorded after proper cleaning.
2. The air-dry sample was weighed and sieved successively on the appropriate sieves starting with the largest size sieve. Care was taken to ensure that the sieves were clean before use.
3. Sieving was carried out with a nest of sieves on a sieve shaker for a period of at least 2 minute.
4. The retained materials on each successive sieve were weighed together with the sieve and recorded.
5. Calculate the weight of aggregate retained on each sieve.

➤ Determination of Bulk Unit Weight of Coarse Aggregate

Scope: - This test method covers the determination of compact weight of coarse aggregate.

Procedure:

1. First we filled the container about one third full with the thoroughly mixed coarse aggregate by means of a shovel.
2. Then we gave the required number of compact blows (25 times) to the aggregate, each blow being given by allowing the tamping rod to fall freely from a height 50 mm above the surface of the aggregate, the blows being evenly distributed over the surface.
3. Then we added a further similar quantity of aggregate in the same manner and gave the same number of blows.
4. Finally we filled the container to over flowing, tamped it again with the same number of blows, and removed the surplus aggregate by rolling the tamping rod across and in contact with the top of the container, any aggregate which impedes its progress being removed by hand, and added the aggregate to fill any obvious depressions.
5. Then we determined the mass of the aggregate in the container.

➤ Determination of Specific Gravity and Absorption of Coarse Aggregate

Scope: - This test method covers the determination of specific gravity and absorption of coarse aggregate. The specific gravity may be expressed as bulk specific gravity (SSD), or apparent specific gravity.

Procedure:

1. The sample is soaked in water for 24hrs.
2. The test sample was removed from the water and rolled in a large absorbent cloth until all visible films of water removed. The larger particles were wiped individually. To avoid evaporation of water from aggregate pores during the surface dry operation the sample was covered. The test sample was in the saturated surface dry (SSD) condition and the weight was recorded to the nearest 0.1gm.
3. A wire mesh basket which is hanged from the balance was immersed in the container and the weight was tarred.
4. Then, immediately the SSD test sample was put in the basket and immersed in the container and the weight is recorded at room temperature.
5. The test sample was dried to a constant temperature of 110 °C for 24hrs, and cooled until the aggregate is cool enough to handle and weigh.

➤ Determination of Moisture Content of Coarse Aggregate

Scope: - This is method covers the determination of moisture content of course aggregate by oven-dry method. This method is sufficiently accurate for usual purpose such as adjusting batch weights of concrete. It will generally measure the moisture in the test sample more reliably than the sample can be made to represent the aggregate supply.

Procedure:

We have cleaned a container, dried it and then weigh it and tarred it (that is neglecting the weight of the container). Place the natural sample prepared and weigh the whole (M1). We have placed the container with test sample in the oven and dry at a temperature 110°C. And we have maintained this temperature until the test sample has reached a constant mass for 24hr. We have removed the container and test sample from the oven and allow the whole to cool till it is possible to handle and weigh, after which we weighed the sample on another tarred container (M2).

3.5.2.2. Fine Aggregate Tests

➤ Determination of Gradation and Fineness Modulus of Fine Aggregate

Objective: - This test method covers the determination of particle size distribution by sieving.

Procedure:

1. The sieves and the pan were weighed and recorded after proper cleaning.
2. The air-dry sample was weighed and sieved successively on the appropriate sieves starting with the largest size sieve. Care was taken to ensure that the sieves were clean before use.
3. Place the 500gm sample on the top sieve
4. Sieving was carried out with a nest of sieves on a sieve shaker for a period of at least 2 minute.
5. The retained materials on each successive sieve were weighed together with the sieve and recorded.

➤ Determination of Bulk Unit Weight of Fine Aggregate

Objective: - To determine the bulk density of fine aggregate (sand)

Procedure: First, we measured the weight of an empty container having a volume of 0.003m³. Then, the container is filled in three layers, each layer being tamped with 25 blows with standard tamping rod. Finally, the excess layer is trimmed off and we weighed it on a balance.

➤ Determination of Specific Gravity of Fine Aggregate

Objective: - To determine bulk and apparent specific gravity of fine aggregates

Procedure:

1. 500g of fine aggregate sample was added immediately in to the pycnometer and filled with water to approximately 90% of the capacity
2. In order to eliminate all air bubbles the pycnometer was rolled, inverted and agitated. Finally the level of water was brought to the calibrated capacity of the pycnometer
3. Then the total weight of the pycnometer, sample and water was determined and recorded.

4. The fine aggregate was removed from the pycnometer in order to dry in an oven, and then cooled at a room temperature for about an hour and then the dried sample was measured.

➤ Determination of Absorption of Fine Aggregate

Objective: To determine absorption of the fine aggregates

Procedure:

1. We soaked the sample of sand that we obtained by using a sample splitter in water.
2. We weighted the sand at SSD condition.
3. After weighing, we immediately placed the SSD test sample an oven at a temperature of 105-115°C for 24 hrs.
4. Finally we took out the sample from the oven and cooled it in a room temperature till it was comfortable to handle, and weighed.

➤ Determination of Moisture Content of Fine Aggregate

Objective: - The objective of this test is to determine the moisture content of fine aggregate.

Procedure:

1. A sample of fine aggregate from sample splitter was taken and weighted.
2. The sample was then oven-dried for 24hrs with a temperature of 105 °C – 110 °C.
3. After 24 hr of oven-dry the samples was removed from the oven cooled for about an hour without absorbing water from the atmosphere.
4. Then the oven dry weight of the aggregate was measured after cooling.

➤ Determination of Silt Content of Fine Aggregate

Objective: - To determine the silt content of a fine aggregate sample

Procedure:

1. A sample of fine aggregate from sample splitter was taken.
2. Take a jar having a capacity of 500ml and pour 125ml (1/4 of the jar) of sand.
3. Fill 3/4 of the jar with water and shack vigorously for about a minute.
4. leave the cylinder for 24 hours and allow the silt to settle on the layer of the sand
5. Measure the layers forming.

3.5.2.3. HCB Test

➤ Compressive strength test

Objectives: - to determine the compressive strength of HCB.

Procedure:

1. Measure the dimension of each block for a check
2. Make the contact surfaces with the testing machine of each sample plane by capping with 1:1 mortar of 2 to 3cm thickness (ES C.D4.001). The caps shall be aged for at least 24 hours before the samples are tested.
3. Place each samples in a position such that the load is applied in the same direction as in service.
4. Apply the compressive force at the rate of 0.2 – 0.5 N/mm² until the sample breaks.
5. Record the maximum load

➤ Water absorption test

Objective: - to determine the amount of water absorbed in a saturated situation.

Procedure:

1. Immerse completely the test specimens (3) in water at room temperature for 24 hours.
2. The specimens shall be weighed, while suspended by a metal wire and completely submerged in water (C).
3. Remove from the water and allowed to drain for 1 minute, visible surface water being removed with damp cloth and immediately weighed (A).
4. All specimens shall be dried in a ventilation oven at 100°C to 115°C not for less than 24 hours and until two successive weighing at the interval of 2 hours show an increment of loss not greater than 0.2 percent.

➤ Block density determination

Objective: - to determine the blocks density which mainly affected by the holes.

Procedure:

1. Drying three specimens in an oven dry at 105°C for 24 hours.
2. After cooling the blocks t a room temperature measure the dimensions and the mass of each specimen.
3. Calculate the density by dividing the mass to the volume of the blocks

3.6. Data Processing and Analysis

The data needed for this research was collected from different journals, book, website etc. during the literature review. All data's that obtained from the laboratory of this study was analyzed by using Microsoft Excel. After the data was analyzed, then it presented by using frequency distribution table, bar graph and pie chart.

3.7. Summary of Methodology

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

Stage I: Literature review

A comprehensive literature review is made to understand the previous efforts, which include the review of textbooks, standards, academic journals, and research papers.

Stage II: Main Investigation

The methods followed to achieve the objectives are:

- Observations on site activities and interviewing the owners, production managers, and workers were made on those production sites.
- Experimental studies were made on the samples from each production sites.
- Compare the results with the recommended standards.
- Based on the findings conclusions are drawn and recommendations are forwarded.

CHAPTER FOUR

4 RESULT AND DISCUSSION

4.1. Production Processes of Aggregates and HCB

4.1.1. Coarse Aggregate

i. Wenago Aggregate Production Site

Profile of the production site

Owner: - China Railway#3 Engineering Group

Location: - in gedeo zone, wenago wereda, around 20km away from dilla in the south west.

Products: - aggregate of different size (00, 01, 02, 03, 04 and 05)

Resources

There are two sources of stone for this production site

1. Stone from the surrounding in the site called wenago and
2. Stone from the Ase gona site in the guji zone which around 7 km away from wenago

Machineries

In this production site there are different machineries used in the different stage of production of aggregate. Such as

- **Crusher:** - the modern type of crusher is used in this production site both the movable one and the fixed one. The crusher currently working is the one called Mc Closky which have the production rate of 500 -700m³ aggregates per day. This crusher is movable with the wheels at the bottom as seen in the figure below. As the production manager Mc Closky costs around 37 million Ethiopian birr.
- **Excavator:** - this used in the ase gona site to excavate and to collect crushed stone. In the wenago site mainly to collect the crushed stones and to primarily crush the stones from each sources which are not fit to the crushing machine.
- **Loader:** - to load the stones in the sources and the products in to those hauling trucks or sino trucks.
- **Damp trucks:** - these trucks (sino trucks) are mainly used to collect the crushed stones from the sources to the production sites particularly to the crushing machine.

Production process

The production mechanism of this site uses modern way of production using drilling in the Ase Gona quarry site and blasting in the one the production machineries are exist which is the Wenago site. To describe the stages in the production process it's better to classify in to three.

Stage -1- Extraction of Resources

The production of aggregate starts from collecting the resources, as I describe above there are two resources in this production site. The wenago stone is first crushed by blasting. As the production manager of the site Mr. Tesfu they are licensed from mining and energy minister to take dynamite to extract the stones. The blasting process is done with the collaboration of police. They first drill up to 60 holes and puts the dynamites and inserts power jell on it and connect the wire that blast the dynamites. After the preparation of dynamites and clearing the surrounding up to 250m distance from living things and machineries the blasting will takes place.

Stage -2- Pre-Crushing

The process next to the extraction of resources is to collect and move it to the crushing machine and dump around it. Those stones which are larger for the crusher will be crushed again using jack hammering. Jack hammering is the technique of reduction the larger size stones by hammering using strong metal rod operate mechanically or attached to excavators.

Jack hammering



Figure 4.1 Pre-Production Crushing on wenago crushing site

Stage -3- Crushing

After the hammering process the crushed stone will be ready for crushing machine then it inserted to Mc Closky crushing machine. This machine has three parts,

- i. **J-50:** - this is the first part of the machine which the hammered stone introduced to. The main function of this part of the machine is to reduce the size of crushed stone and to eliminate the clays that are attached to the stones.



Figure 4.2 the primary crusher (J-50) on wenago crushing site

- ii. **C-44:** - this is the second part of the machine; it is adjustable to the maximum size of aggregate to be produced in the site in our case 02 aggregate. This machine also reduces the size of the crushed aggregate from the previous machine (**J-50**).



Figure 4.3 the secondary crusher (C-44) on wenago crushing site

- iii. **S-190 (Screen):** - this is the third part of the machine; their function is to screen the crushed aggregates in the two previous parts of the machines (**J-50 & C-44**) according to their size.



Figure 4.4 the screen (S- 190) on wenago crushing site

Therefore the aggregate production follows the above three stages and finally the products will be ready for use. As I mentioned the products of the company are 00, 01 and 02 currently.

Handling the products

After the production processes are finished they collect the product and transport to the storage area using dump trucks according to their size. The storage area is not far away from the production machineries. They have huge amount of aggregate stored in their production yard.

ii. Waleme Aggregate Production Site

Profile of the production site

Owner: - Ame Gebato group

Location: - in gedee zone, Diila wereda, around 4km North West of dilla town.

Products: - aggregate of different size (01, 02, 03 and 04)

Resources

The resource used in this production site is the waleme stone all in the surrounding of the production yard.

Machineries

In this production site there is only one machine which used to crush and screen the aggregate after primarily crushed by labor force.

- Small Crusher: - this small type of crusher is fixed in the site and does only one time crushing and screening.

Other than this machine there is no other machine used in the resource drilling process, in the pre crushing stage and also in the collection and storing of the products.



Figure 4.5 Small Crushing Machines on Waleme Crushing Site

Production process

The production mechanism of this site is using labor force to drill the resource which is a mountain of stone and crush it until the appropriate size appeared still using labor force. There is no primary and secondary crushing machine at all.

To describe the stages in the production process it's better to classify in to three.

Stage -1- Extraction of Resources

The production of aggregate starts from collecting the resources, as I describe above there is only one source which is the waleme stone. The process of extraction stone uses labor force there is no blasting or drilling using machineries. The extracted stone is also delivered to the production yard by using labor force which is very difficult to transport stone by carrying due to the distance and the geographical features.



Figure 4.6 Extracting Stones Manually



Figure 4.7 Transporting Resources Manually

Stage -2- Pre-Crushing

The process next to the extraction of resources is to collect and move it to the crushing machine. The stones should be crushed primarily with hand and reduce the size before inserting it to the crushing machine.



Figure 4.8 Crushing Manually on waleme crushing site

Stage -3- Crushing

After the process in the second stage is done, it will be ready for crushing machine so they transport it to what they call it “the bed” which is a bed like structure constructed from timber at the top of the crushing machine. This machine is operated by four labors at the top (the bed) and other four labors at the bottom of the machine. The four labors at the top inserts the crushed stone using half cut plastic jar and the other four at the top collect the aggregate crushed and screened according to their size 01, 01, 02 and 04 then other labors transports to the storage area.



Figure 4.9 crushed stone ready for the machine



Figure 4.10 transported and stored in the bed



Figure 4.11 crushing portion



Figure 4.12 screening sieves on the machine



Figure 4.13 the Outlet of Each Size Aggregates

Handling the products

After the production processes are finished they collect the product and transport to the storage area using labors according to their size. The storage area is small and due to this products were exposed to mix each other and for the surrounding dust. They have small amount of aggregate of each size stored in their production yard.



Figure 4.14 Stored Products of Each Size

iii. Mechisho Aggregate Production Site

Profile of the production site

Owner: - Mr. Yohanis M.

Location: - in sidama zone, dara wereda, around 8 km away from dilla in the north.

Products: - aggregate of different size (00, 01, 02 and 03)

Resources

The resource used in this site is “the Adame Stone” which is also available in the surrounding of the production yard.

Machineries

In this production site also there is only one machine which used to crush and screen the aggregate after primarily crushed by labor force.

- Small Crusher: - this small type of crusher is fixed in the site and does only one time crushing and screening.

As the waleme crushing site in mechisho crushing site also there is no other machine used in the resource drilling process, in the pre crushing stage and also in the collection and storing of the products.

Production process

The production mechanism of this site is also using labor force to drill the resource which is a mountain of stone and crush it until the appropriate size appeared still using labor force. There is no primary and secondary crushing machine at all.

To describe the stages in the production process it’s better to classify in to three.

Stage -1- Extraction of Resources

The production of aggregate starts from collecting the resources, as I describe above there is only one source which is the Adame stone. The process of extraction stone uses labor force there is no blasting or drilling using machineries. The extracted stone is also delivered to the production yard by using labor force which is very difficult to transport stone by carrying due to the distance and the geographical features.

Stage -2- Pre-Crushing

The process next to the extraction of resources is to collect and move it to the crushing machine. The stones should be crushed primarily with hand and reduce the size before inserting it to the crushing machine.



Figure 4.15 Crushed Manually in Mechisho Crushing Site

Stage -3- Crushing

After the process in the second stage is done, it will be ready for crushing machine so they transport it to what they call it “the bed” which is a bed like structure constructed from timber at the top of the crushing machine. This machine is operated by four labors at the top (the bed) and other four labors at the bottom of the machine. The four labors at the top inserts the crushed stone using half cut plastic jar and the other four at the top collect the aggregate crushed and screened according to their size 01, 01, 02 and 04 then other labors transports to the storage area.



Figure 4.16 ready crushed stone for the machine



Figure 4.17 transported and stored in the bed



Figure 4.18 crushing portion



Figure 4.19 screening sieves on the machine

Handling the products

After the production processes are finished they collect the product and transport to the storage area using labors according to their size. The storage area is small and due to this products were exposed to mix each other and for the surrounding dust. They have small amount of aggregate of each size stored in their production yard.



Figure 4.20 Stored Products of Each Size

iv. Golla Aggregate Production Site

Profile of the production site

Owner: - Mr. Cherinet Chane

Location: - in gedeo zone, dilla zuriya wereda, around 6 km away from dilla in the east.

Products: - aggregate of different size (00, 01, 02, 03 and 04)

Resources

The source of the aggregate production site is the Gola stone from gola kebele where already the site exists.

Machineries

In this production site there are different machineries used in the different stage of production of aggregate. Such as

- **Crusher:** - The crusher used in this production site is the one called Impact Crusher. The production rate of this crushing machine is around 80 – 150 m³ per day. The existing impact crusher machine in this site the old model.
- **Excavator:** - this used mainly to collect the crushed stones and to load the excavated stone to the dump trucks which transports to crushing machine, and also to primarily crush the stones from each sources which are not fit to the crushing machine.
- **Loader:** - to load the stones in the sources and the products in to those hauling trucks or sino trucks.

- Damp trucks: - these trucks (sino trucks) are mainly used to collect the crushed stones from the sources to the production sites particularly to the crushing machine.

Production process

The production mechanism of this site uses modern way of production using drilling in the gola mountain quarry site. To describe the stages in the production process it's better to classify in to three.

Stage -1- Extraction of Resources

The production of aggregates starts from collecting the resource from Gola mountain quarry site. The excavation takes place in this site using both labor force and excavating machines. After the stone is excavated it will transport to the production yard by damp trucks.

Stage -2- Pre-Crushing

The process next to the extraction of resources is to collect and move it to the crushing machine and dump around it. Those stones which are larger for the crusher will be crushed again using jack hammering sometimes using labor force.

Stage -3- Crushing

After the hammering process the crushed stone will be ready for crushing machine then it inserted to Impact crushing machine. This machine has three parts,

- Primary crusher:** - this is the first part of the machine which the hammered stone introduced to. The main function of this part of the machine is to reduce the size of crushed stone.



Figure 4.21 Primary Crusher of Golla Crushing Site

- ii. **Secondary crusher:** - crushed stone in the primary crushing stone will transported to secondary crushing machine using the lifts attached to both machines. This machine also reduces the size of the crushed aggregate from the previous machine.



Figure 4.22 Secondary crusher of Golla crushing site

- iii. **Tertiary crusher:** - this is the third and the final crushing machine which crushes those aggregates that needs further crushing and do the screening of aggregates on their respective size.



Figure 4.23 Screening in Golla Crushing Site

Therefore the aggregate production follows the above three stages and finally the products will be ready for use. As I mentioned the products of the company are 00, 01 and 02 currently.

Handling the products

After the production processes are finished they collect the product and transport to the storage area using dump trucks according to their size. The storage area is not far away from the production machineries. They have huge amount of aggregate stored in their production yard.

➤ **General Discussion of Coarse Aggregate Production**

As observed the production some aggregate production sites are good and some of them should be improved. The wenago aggregate production has the best production processes and also the golla aggregate production site. Especially the wenago production site follows almost all the production processes explained in the literature review. The extraction process, the transportation, the crushing, screening and the handling mechanisms followed in wenago site are all recommended. In the other hand the production mechanism in walleme and mechisho aggregate production sites are the one which needs improvement. On the extraction process both sites uses labor forces which affects once the production rate as well as the safety and health of the workers. On the transportation process they uses again the labor force which also has the same effect, and in the crushing process they only crush one time in the crushing machine which mainly affect the quality of aggregates produced especially with respect to its gradation. No secondary and tertiary crushing in both walleme and mechisho crushing sites. In handling of the produced aggregates all the production site has the same mechanism which is not the best way to handle aggregate products. The golla crushing site followed also best production processes, the main difference between the wenago production site and the golla production site is the machine they uses in the crushing which the wenago crushing site uses more modern and movable crushing machine.

4.1.2. Fine Aggregate Production

Sand production practice used in all sites I visited and investigated in this research which exists and near to gedeo zone is natural sand production technique. All sites the gidabo sand, the kilkile sand and the hantate sand are produces fine aggregate using the same procedure. Since the production process they were following was the same, here below I showed the process in general.

➤ **Sand Production sites**

i. The Gidabo Site

Location: - in western guji zone, abaya wereda, around 17 km away from dilla in the west.

Producers: - the producers are different and allot in number that surround the Gidabo River. Some are private and some are youth from village organized by the government.

ii. The Kilkile Site

Location: - in gedeo zone, gedeb wereda, around 59 km away from dilla in the south.

Producers: - the producers are different and allot in number that surround the kilkile River. Some are private and some are youth from village organized by the government.

iii. The Golelicha Site

Location: - in sidama zone, around 70 km away from dilla in the south.

Producers: - the producers are different and allot in number that surround the hantate River. Some are private and some are youth from village organized by the government.

➤ **Sand Production process**

Extracting the natural sand deposited in the river and transporting it to the place they load the mass are all the process in all the sand production sites.

Stage One – Extracting the Sand

They extract the sand from the river flows which deposited sand on it. The tool used in the extraction process is mainly shovel. Labors dress half necked and drove themselves in to the river and using shovel extract the sand from the deep and first deposit it on the temporary storage place they provide in the middle of the river as shown below in the figure.



Fig. 4.24 Sand Production (extraction and temporarily depositing)

Stage Two – Transporting To the Storage

After the extraction process is done the next is to collect and store the sand which is ready to sell. Transporting the sand is done by mainly labor force and animals also used.



Figure 4.25 Transporting To the Permanent Storage

➤ General of Fine Aggregate Production

The production processes of fine aggregates are similar in all sites investigated. Natural sands are used in gedee zone which excavated from river bed. The entire three fine aggregate production sites follows the same procedures, extracting from river bed, store temporarily and then transport it to its main storage using labor force and donkey. The main problem was the extraction as well as the handling mechanism exposed to contamination from the environment like clay, which leads to produce high silt content sand. It also highly affected by organic impurity.

4.1.3. Hollow concrete block production

i. Zemenu HCB and terrazzo production site

Company Profile

- **Owner:** - Zemenu HCB and Terrazzo production is established in 2008 E.C. in the ownership of Ato Zemenu Ashenafin.
- **Location:** - Zemenu HCB and Terrazzo production is located in dilla town, harro welabu sub city, harroresa kebele, around gedee zone administration building.
- **Products:** - they produce different types of HCB with different classes and terrazzo tile. Among the products, 10cm, 15cm, 20cm, and ribbed slab in class A, B and C. Their production is only limited to user's desire specially 10cm and ribbed slab HCB. Class A and B of HCB is only produced when there is order from users but

since 20cm and 15cm HCB in class C is mainly used in most of the construction sites they produce every day.

- **Users:** - the main users for zemenu's HCB and terrazzo production are private home builders, private constructors (sunshine construction in their dilla referral hospital project and other contractor) and sometimes public body.

Resources

For the production of HCB they use different materials and these materials had been collected from different sources. These are

- ✓ **Cement** they use dangote cement (42.5R)
- ✓ **Sand** from hantate (sidama zone)
- ✓ **Komche** from sidama zone around wendo
- ✓ **Bole** from shashemen
- ✓ **Water** from chichu river



Figure 4.26 - hantate sand, komich, bole and aggregate in zemenu hcb production

Production process

Zemenu's productions produces different type of HCB with different classes but most of them are produced only when there is a mass of orders. So, their main product is HCB 15cm and 20cm in class C. hence I was able to watch the production process these HCB products. The production process of HCB involves Proportioning, Mixing, Molding, Compacting & placing and Curing.

a. Mix design (proportioning)

To produce HCB the proportion they use is measured by volume of the box which has a dimension of 50*40*20cm. Hence, the method of proportioning (batching) is volume batching. Table 4.1 below discusses the proportioning of raw materials for different classes of HCB produced in this production.

Table 4.1 – Proportioning in zemenu HCB production

Raw materials		Amount of material in each Class of HCB		
		Class A	Class B	Class C
Coarse Aggregate size, in box	00	1		
	01	1	2	
Sand, in box		1	2	2
Cement, in bag		1	1	1
Komiche, in box				6
Admixture				
Bole soil, in box				1
Water, in liter		40	40	40-60
Average number of HCB produced per mix	20cm HCB	25	40	30
	15cm HCB	30	45	35
	10cm HCB	40	50	40

➤ **Ribbed Slab**

The same type of batching as the previous is used

- Sand = 1 box
- Kmiche = 4 box
- Bole Soil = 1 box
- Cement = 1 bag and
- Water = 40 - 50 liter

Using this proportion of materials they produce an average of 40 ribbed slab is produced.



Figure 4.27 - sample ribbed slab produced in zemenus HCB production

b. **Mixing**

Based on the proportion of materials described above; mixing will takes place near to the production machine. Sand is measure first then komiche and bole is added and then cement. After mixing this ingredients properly 2 – 3 time then water is introduced gradually. Again mixing continues 2 – 3 time. Finally the mix is ready to be molded.



Figure 4.28 - water storage and mixing process in zemenu HCB production

c. **Molding**

The third process in HCB production after proportioning and mixing is molding and producing with the required size and shape. This is achieved by putting the ready mixed materials to the molding machine. The mold is different based on the size of HCB (20cm, 15cm or 10cm) to be produced. Each HCB size has its own mold. Hence, after adjusting the required mold on machine and this process require at least 5 peoples. One person operates the machine; other fills the mold with the mix, the third person puts the timber plate at the bottom of mold and finally the last two peoples takes the product to the shed where HCB's temporarily store for 24 hours.



Figure 4.29 - molding of HCB in zemenu HCB production

d. Compacting and Placing

Compacting and placing are the processes right after molding the mix. After putting the mix in molding machine about 1m vibration requires as some literatures but here less vibration is applied about half of a minute. Following the compaction for about 30 seconds the product is taken to the shade and placed there for about 24 hours.



Figure 4.30 - placing of HCB in zemenu HCB production

e. Curing

The final procedure in HCB production is curing. Here in zemenus HCB production after 1 day the produced HCB dried in normal room temperature on the shed they move out it to the environment and exposes to sun. Curing starts after 24 hour of age after production and it continues 5 – 7 days. During curing stage the arrangement of HCB is changed to squashing one on other in order to reduce place wastage and curing takes place morning and night.



Figure 4.31 - curing of HCB in zemenu HCB production

f. Testing

Testing the product if it compliance the standard or the strength it produced for is not practiced here. The only test they perform is throwing down the HCB from persons waist and see if it is broken or not. This test performed by some contractors but most of the time no throwing down test even performed.

ii. Walelign HCB Production Site

Company Profile

- **Owner:** - Walelign HCB production is established in 2007 E.C. in the ownership of Ato Walelign Million.
- **Location:** - Walelign HCB production is located in dilla town, Sesa sub city, Oda'aya kebele, around Abenezzer hotel.
- **Products:** - they produce different types of HCB with different classes. Among the products, 10cm, 15cm, 20cm in class A, B and C and ribbed slab, circular and half circle pipes are also produced. Their production is only limited to user's desire specially 10cm and ribbed slab HCB and also those ditch pipes. Class A and B of HCB is only produced when there is an order from users but since 20cm and 15cm HCB in class C is mainly used in most of the construction sites they produce every day.
- **Users:** - the main users for Walelign's HCB production are mainly the owner himself as he is a private contractor, private home builders, other private constructors (FE construction) and sometimes public body.

Resources

For the production of HCB they use different materials and these materials had been collected from different sources. These are

- ✓ **Cement** they use dangote cement (32.5R)
- ✓ **Sand** from gidabo (west guji zone)
- ✓ **Komche** from sidama zone around hawassa and sometimes from adama
- ✓ **Bole** from sidama zone
- ✓ **Water** from legedara river



Figure 4.32 - komich, bole, sand and water storage in walelign's hcb production

Production process

Walelign's production produces different type of HCB with different classes but most of them are produced only when there is an order as Zemenu's production does. So, their main product is HCB 15cm and 20cm in class C. hence I was able to watch the production process these HCB products fortunately I was also able to see 10cm HCB production because by the time I visit there was order for 10cm HCB. The production process in Walelign HCB production is the same as in Zemenu HCB production.

a. Mix design (proportioning)

Unlike other production sites in Walelign HCB production the materials are measured by cement bags. Table 4.2 below discusses the proportioning in wallelign HCB production.

Table 4.2 – Proportioning in wallelign HCB production

Raw materials		Amount of material in each Class of HCB		
		Class A	Class B	Class C
Coarse Aggregate size, in bag	00	3	2	
	01			
Sand, in bag		1	1	1
Cement, in bag		1	1	1
Komiche, in bag		1	1.5	8
Red ash, in bag			1	
Admixture				
Bole soil, in bag		1	1	1
Water, in liter		50	50	45
Average number of HCB produced per mix	20cm HCB	25	30	27
	15cm HCB	30	35	33
	10cm HCB	35	40	38
	Ribbed blocks	20	25	18

b. Mixing

Based on the proportion of materials described above; mixing will take place near to the production machine. Sand is measured first then komiche and bole is added and then cement. After mixing these ingredients properly 3 times then water is introduced gradually. Again mixing continues 2 times. Finally the mix is ready to be molded.



Figure 4.33 - mixing process in Waleign HCB production

c. Molding

The third process in HCB production after proportioning and mixing is molding and producing with the required size and shape. This is achieved by putting the ready mixed materials to the molding machine. The mold is different based on the size of HCB (20cm, 15cm or 10cm and Ribbed slab) to be produced. Each HCB size has its own mold. Hence, after adjusting the required mold on machine and this process requires at least 5 people. One person operates the machine; another fills the mold with the mix, the third person puts the timber plate at the bottom of the mold and finally the last two people take the product to the shed where HCB's temporarily store for 24 hours.



Figure 4.34 - molding of HCB in Walelign HCB production

d. Compacting and Placing

Compacting and placing are the processes right after molding the mix. After putting the mix in molding machine about 1m vibration requires as some literatures but here less vibration is applied about half of a minute. Following the compaction for about 30 seconds the product is taken to the shade and placed there for about 24 hours.



Figure 4.35 - compacting and placing of HCB in Walelign HCB production

e. Curing

Here in walelign HCB production the curing process starts from the 2nd day after production and it continues to 4th day and in the 5th day the product is ready for use. During curing stage the arrangement of HCB is changed to squashing one on other in order to reduce place wastage and curing takes place morning and night.

f. Testing

There is no practice of performing HCB tests in walelign HCB production site. They only focus on the mix proportion to be sure that the product has the required class or strength.

iii. Hibret HCB Production Site

Company Profile

- **Owner:** - Hibret HCB production is established in 2009 E.C. in the ownership of Ato Seifu Mekuriya.
- **Location:** - Hibret HCB production is located in dilla town, harro welabu sub city, harroresa kebele, around Michael church.
- **Products:** - they produce different types of HCB with different classes. These are 15cm, 20cm in class A, B and C. Their production is only limited to user's desire specially Class A and B of any size HCB is only produced when there is an order from users but since 20cm in class C is mainly used in most of the construction sites they produce every day.
- **Users:** - the main users for Hibret HCB production are mainly the private home builders, other private constructors and sometimes public body.

Resources

For the production of HCB they use different materials and these materials had been collected from different sources. These are

- ✓ **Cement** they use Habesha cement (32.5R)
- ✓ **Sand** from randome (gidabo sand at the time of investigation)
- ✓ **Komche** from sidama zone around hawassa
- ✓ **Bole** from sidama zone
- ✓ **Water** from waleme river

Production process

Hibret production produces different type of HCB with different classes but most of them are produced only when there is an order. So, their main product is HCB 15cm and 20cm in class C. hence I was able to watch the production process these HCB products.

a. Mix design (proportioning)

To produce class C HCB the proportion they use is measured by volume of the box which has a dimension of 50*40*20cm. Hence, the method of proportioning (batching) is volume batching. Table 4.3 below discusses the proportioning of raw materials for different classes of HCB produced in this production.

Table 4.3 – proportioning in hibret HCB production

Raw materials		Amount of material in each Class of HCB		
		Class A	Class B	Class C
Coarse Aggregate size, in box	00	1		
	01	1	2	
Sand, in box		1	2	1
Cement, in bag		1	1	1
Komiche, in box			1	5
Admixture				
Bole soil, in box				1
Water, in liter		50	50	50
Average number of HCB produced per mix	20cm HCB	25	30	25
	15cm HCB	30	35	30
	10cm HCB	35	40	35

b. Mixing and molding

Here in Hibret HCB production the mixing and molding process has no difference with the previous HCB production sites.

c. Compacting and Placing

The main difference in Hibret production is in the process of compaction as compared to the others they almost vibrate it for a minute. Following the compaction the product is taken to the shade and placed there for about 24 hours.

d. Curing

Here in Hibret HCB production the curing process starts from the 2nd day after production and it continues to 7th day and in the 8th day the product is ready for use. During curing stage the arrangement of HCB is changed to squashing one on other in order to reduce place wastage and curing takes place morning and night.

iv. Berta HCB Production

Company Profile

- **Owner:** - Berta HCB production is established in 2005 E.C. in the ownership of 5 members of Berta group.
- **Location:** - Berta HCB production is located in dilla town, harro welabu sub city, harroresa kebele, around 15th road.
- **Products:** - they produce different types of HCB with different classes. These are 10cm, 15cm, 20cm in class A, B and C and ribbed slab. Their production is only limited to user's desire specially Class A and B of any size HCB and 10cm, 15cm and ribbed slab of any classes are also produced when there is an order from users but since 20cm in class C is mainly used in most of the construction sites they produce every day.
- **Users:** - the main users for Berta HCB production are mainly the private home builders, private constructors and sometimes public body.

Resources

For the production of HCB they use different materials and these materials had been collected from different sources. These are

- ✓ **Cement** they use Dangote cement (32.5R)
- ✓ **Sand** from randome (hantate sand at the time of investigation)
- ✓ **Komche** from sidama zone around hawassa tikur wuha
- ✓ **Bole** from sidama zone
- ✓ **Water** from waleme river

Production process

As most of the site the production process followed in Berta production are the same but the main difference is the proportion of materials they use. They produce different type of HCB with different classes but most of them are produced only when there is an order. So, their main product is HCB 15cm and 20cm in class C. hence I was able to watch the production process these HCB products.

a. Mix design (proportioning)

To produce class C HCB the proportion they use is measured by volume of the box which has a dimension of 50*40*20cm. Hence, the method of proportioning (batching) is volume batching.

Table 4.4 – proportioning in Berta HCB production

Raw materials		Amount of material in each Class of HCB		
		Class A	Class B	Class C
Coarse Aggregate size, in box	00	1	1	
	01	2	1	
Sand, in box		2	2	1
Cement, in bag		1	1	1
Komiche, in box			2	5
Admixture				
Bole soil, in box				1
Water, in liter		45	45	45
Average number of HCB produced per mix	20cm HCB	25	40	30
	15cm HCB	30	45	35
	10cm HCB	40	50	40

b. Mixing

The only difference from other HCB production sites I visit in mixing is they mix the ingredients properly 2 time then water is introduced gradually and again mixing continues 3 times. Finally the mix is ready to be molded.

c. Molding

There is no difference in molding and vibrating process in Berta production with those production sites I investigate vibrating mostly ends in less than a minute.

d. Compacting and Placing

Compacting and placing are the processes right after molding the mix. After putting the mix in molding machine about 1m vibration requires as some literatures but here less vibration is applied about half of a minute. Following the compaction for about 30 seconds the product is taken to the shade and placed there for about 24 hours.

e. Curing

Here in Berta HCB production the curing process starts from the 2nd day after production and it continues to 7th day after that they will be air dried and the product is ready for use. During curing stage the arrangement of HCB is changed to squashing one on other in order to reduce place wastage and curing takes place morning and night.

f. Testing

There is no practice of performing HCB tests in Berta HCB production site. They only focus on the mix proportion to be sure that the product has the required class or strength.

v. **Chefe HCB Production**

Company Profile

- **Owner:** - Chefe HCB production is established in 2008 E.C. in the ownership of 5 members of chefe group.
- **Location:** - chefe HCB production is located in yirga chefe town.
- **Products:** - they produce different types of HCB with different classes. These are 15cm, 20cm in class A, B and C. but they constantly produce 20cm HCB in class C.
- **Users:** - the main users for chefe HCB production are mainly the private home builders in town, private constructors and sometimes public body.

Resources

For the production of HCB they use different materials and these materials had been collected from different sources. These are

- ✓ **Cement** they use Dangote cement (32.5R)
- ✓ **Sand** from randome (kilkile sand at the time of investigation)
- ✓ **Komche** from sidama zone aound wendo
- ✓ **Bole** from sidama zone
- ✓ **Water** from chefe river

Production process

The production process followed in Chefe production are the as most of the site I visit.

a. Mix design (proportioning)

To produce class C HCB the proportion they use is measured by volume of the box which has a dimension of 50*40*20cm. Hence, the method of proportioning (batching) is volume batching.

Table 4.5 – proportioning in chefe HCB production

Raw materials		Amount of material in each Class of HCB		
		Class A	Class B	Class C
Coarse Aggregate size, in box	00	1	1	
	01	2	1	
Sand, in box		2	2	1
Cement, in bag		1	1	1
Komiche, in box			2	5
Admixture				
Bole soil, in box				1
Water, in liter		40	40	40
Average number of HCB produced per mix	20cm HCB	25	40	30
	15cm HCB	30	45	35
	10cm HCB	40	50	40

b. Mixing

The only difference from other HCB production sites I visit in mixing is they mix the ingredients properly 2 time then water is introduced gradually and again mixing continues 3 times. Finally the mix is ready to be molded.

c. Molding

There is no difference in molding and vibrating process in Berta production with those production sites I investigate vibrating mostly ends in less than a minute.

d. Compacting and Placing

Compacting and placing are the processes right after molding the mix. After putting the mix in molding machine about 1m vibration requires as some literatures but here less

vibration is applied about half of a minute. Following the compaction for about 30 seconds the product is taken to the shade and placed there for about 24 hours.

e. Curing

Here in Berta HCB production the curing process starts from the 2nd day after production and it continues to 7th day after that they will be air dried and the product is ready for use. During curing stage the arrangement of HCB is changed to squashing one on other in order to reduce place wastage and curing takes place morning and night.

f. Testing

There is no practice of performing HCB tests in Berta HCB production site. They only focus on the mix proportion to be sure that the product has the required class or strength.

➤ **General Discussion Of HCB Production**

The HCB production processes are almost similar in all investigated production sites. The main differences are comes in ingredient proportioning stage. To produce class C HCB in zemenu production site 2 box of sand used but the other production sites 1 box of sand used. In all production site there is an ingredient called bole soil, which the property is not studied as well as komiche and these two ingredient needs to be investigated. All the mixing proportions are used in all sites are not the result of any calculation for mix design. Class A and class B grade of HCB was not available in all production sites, only class C HCB grades are available in all site they produces other grades if they received massive orders, and also there are only 20cm and 15cm HCB are available in most sites. The mixing mechanism in all production sites is the same, they uses hand mixing which also its own impact on producing quality HCB. The main problem observed in HCB production process investigation was the compaction duration. The recommended vibration time is at least 1minute but in all production sites less than 30second vibration time is used, which reduces the compaction and reduces the strength and also the density of the block. None of the production sites have no practice of performing a laboratory tests for their products whether the products fulfill the standard requirement or not.

4.2. Properties of Aggregates and HCB

4.2.1. Coarse Aggregate

The coarse aggregates investigated in this research were from four crushing sites that mainly used in gedeo zone construction projects. These aggregates are commonly used in the Dilla town and its surround and as such, are readily available and best simulates normal construction practice in the area. In this study the physical properties of coarse aggregates are investigated and the test results are discussed below.

i. Wenago Aggregate Production

A. Sieve Analysis

Wenago's Aggregate has a better gradation result as shown in the table 4.6 and 4.7 which indicates the sieve analysis result and the standard provided in our country ESC.D3.201 as well as ASTM C 33:2004. In both trials of the sieve analysis test the samples were in the limit of the standards. The other properties results and procedures of Wenago Aggregate are discussed in appendix one.

➤ Trial -1

Table 4.6 Sieve Analysis Test Result for Wenago Coarse Aggregate (trial 1)

sieve Size(mm)	Wt of sample retained (g)	Wt. retained (%)	Cum. % retained	Cum. % pass	ESC.D3.201 limit		ASTM limits		Remark
					lower limit	lower limit	lower limit	upper limit	
37.5	0	0.000%	0.000%	100.000%	100%	100%	100%	100%	OK
25	111.2	4.475%	4.475%	95.525%	95%	100%	95%	100%	OK
19.0	553.6	22.278%	26.753%	73.247%	70%	95%	60%	95%	OK
12.5	902.1	36.302%	63.054%	36.946%	30%	70%	25%	60%	OK
9.5	477.6	19.219%	82.274%	17.726%	10%	30%	10%	25%	OK
4.75	412.9	16.616%	98.889%	1.111%	5%	10%	0%	10%	OK
2.36	19.2	0.773%	99.662%	0.338%	0%	5%	0%	5%	OK
pan	8.4	0.338%	100.000%	0.000%	-	-	-	-	-
Total	2485.0	100.000%							

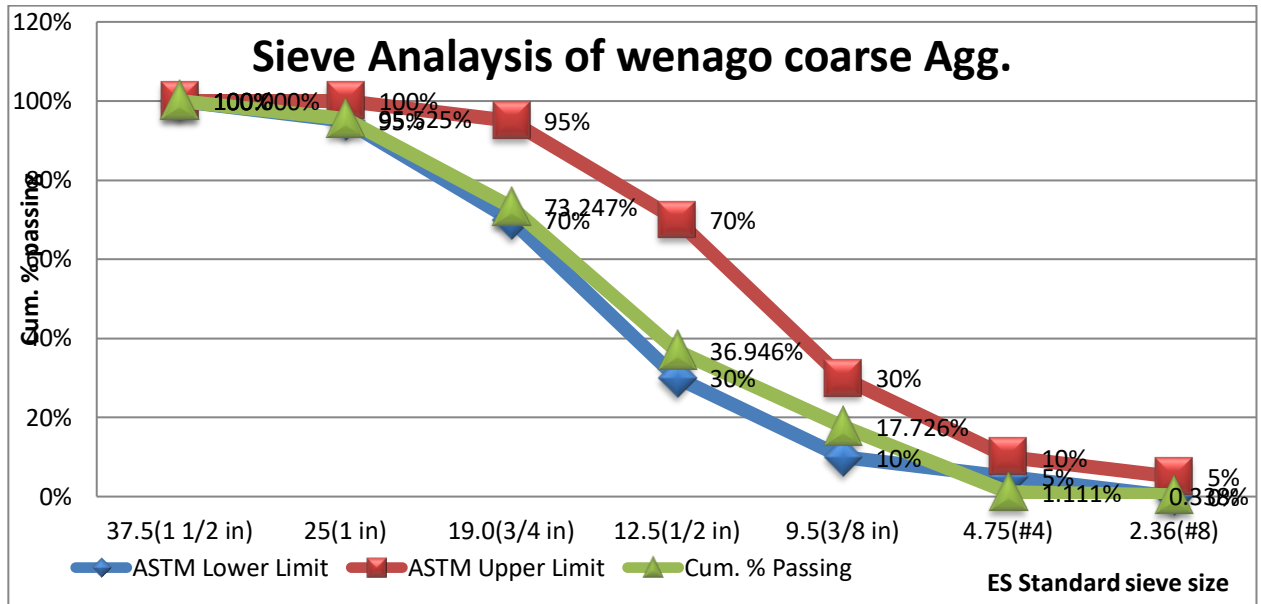


Figure 4.36 - Particle size distribution of Wenago aggregate (trial 1)

➤ Trial two

Table 4.7 Sieve Analysis Test Result for Wenago Coarse Aggregate (trial 2)

sieve Size(mm)	Wt of sample retained (g)	Wt. retained (%)	Cum. % retained	Cum. % pass	ESC.D3.201 limit		ASTM limits		Remark
					lower limit	lower limit	lower limit	upper limit	
37.5	0	0.000%	0.000%	100.000%	100%	100%	100%	100%	OK
25	118	4.726%	4.726%	95.274%	95%	100%	95%	100%	OK
19.0	588.2	23.560%	28.286%	71.714%	70%	95%	60%	95%	OK
12.5	907.2	36.337%	64.624%	35.376%	30%	70%	25%	60%	OK
9.5	404.4	16.198%	80.822%	19.178%	10%	30%	10%	25%	OK
4.75	451.2	18.073%	98.894%	1.106%	5%	10%	0%	10%	OK
2.36	19.2	0.769%	99.664%	0.336%	0%	5%	0%	5%	OK
pan	8.4	0.336%	100.000%	0.000%	-	-	-	-	-
Total	2496.6	100.000%							

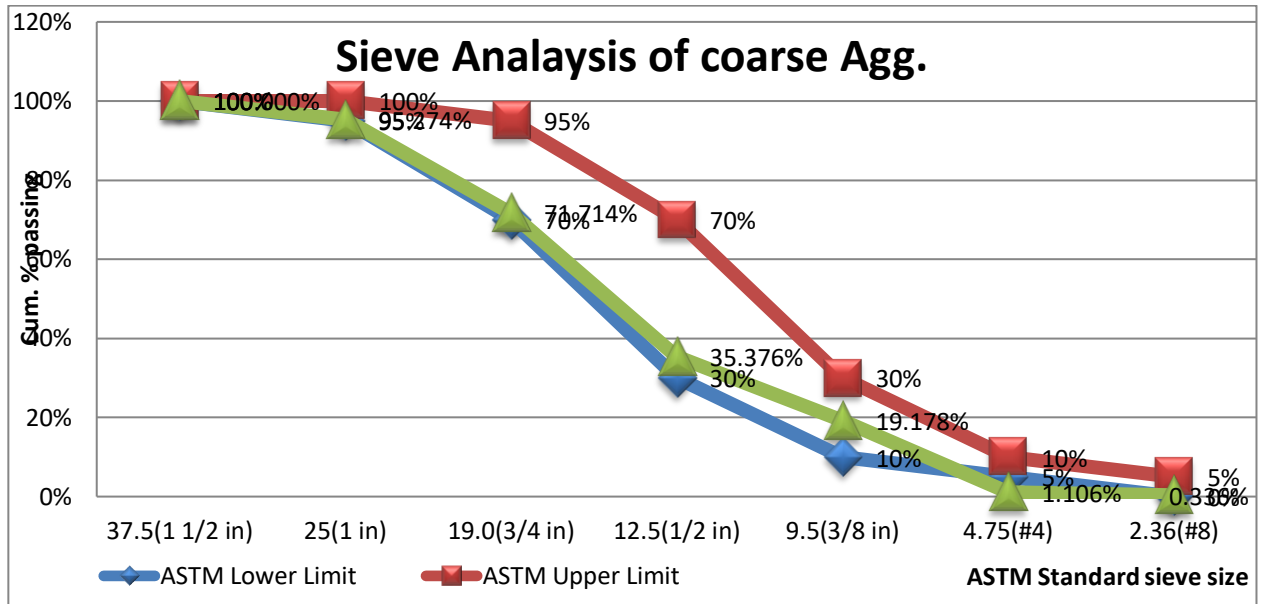


Figure 4.37 - Particle size distribution of Wenago aggregate (trial 2)

B. Summary of other test results

The summary of other physical properties result of wenago's aggregate is discussed below in the table 4.8, I have discussed the procedures and results in the appendix one.

Table 4.8 Summarized Test Results for Wenago Coarse Aggregate

Types of Test		Test Result	Remark
Unit Weight`	Compacted	1641.57Kg/m ³	The result shows that the aggregate is within the recommended limit (1280-1920kg/m³)
	Loose	1535.79Kg/m ³	
Bulk specific gravity	Oven-dry	2.45	The recommended relative density limit in (2.30 – 2.90) and wenago's aggregate has 2.49.
	Saturated & Surface dry	2.49	
	Apparent	2.56	
Water Absorption Capacity		1.77%	The recommended Absorption capacity limit ranges (0.5% – 4%) and wenago's aggregate has 1.77% of Average Absorption capacity
Moisture Content		0.88%	The moisture content of wenago's aggregate is 0.88% which is in the range (0.5 – 2%)

➤ **Discussion on Wenago Aggregate**

Wenago's aggregate has good gradation and it is according to the standard. Since, uniformly distributed size of aggregate make concrete production better, this aggregate is suitable in mixing and producing concrete. The unit weight result of this aggregate which is 1641.57 Kg/m³, show that the aggregate is within the recommended limit (1280-1920kg/m³). The higher the bulk density means the fewer the void in it and good gradation, which reduces the paste in concrete production. The specific gravity result 2.49 is also in the range (2.3 – 2.9) and suitable according to the standard provided. The property that needs a care is its absorption capacity which is greater than its moisture content. The moisture content of wenago's aggregate is less than its absorption capacity (0.88% < 1.77%), it indicate that while using this aggregate the mixing water should increased.

ii. Waleme Aggregate

A. Sieve Analysis

The gradation of waleme's aggregate is not in the limit of both standards. According to sieve analysis result shown in the table 4.9 first trial and table 4.10 second trial this aggregate much coarser than it should be, higher amount of aggregate is retained in 25mm, 19mm and 12.5mm sieve size.

➤ **Trial -1**

Table 4.9 Sieve Analysis Test Result for Waleme Coarse Aggregate (trial 1)

sieve Size(mm)	Wt of sample retained (g)	Wt. retained (%)	Cum. % retained	Cum. % pass	ESC.D3.201 limit		ASTM limits		Remark
					lower limit	lower limit	lower limit	upper limit	
37.5	0	0.000%	0.000%	100.000%	100%	100%	100%	100%	OK
25	682.6	27.314%	27.314%	72.686%	95%	100%	95%	100%	NO
19.0	923.4	36.949%	64.263%	35.737%	70%	95%	60%	95%	NO
12.5	681.6	27.274%	91.537%	8.463%	30%	70%	25%	60%	NO
9.5	156.8	6.274%	97.811%	2.189%	10%	30%	10%	25%	NO
4.75	51.2	2.049%	99.860%	0.140%	5%	10%	0%	10%	NO
2.36	0.8	0.032%	99.892%	0.108%	0%	5%	0%	5%	OK
pan	2.7	0.108%	100.000%	0.000%	-	-	-	-	-
Total	2499.1	100.000%							

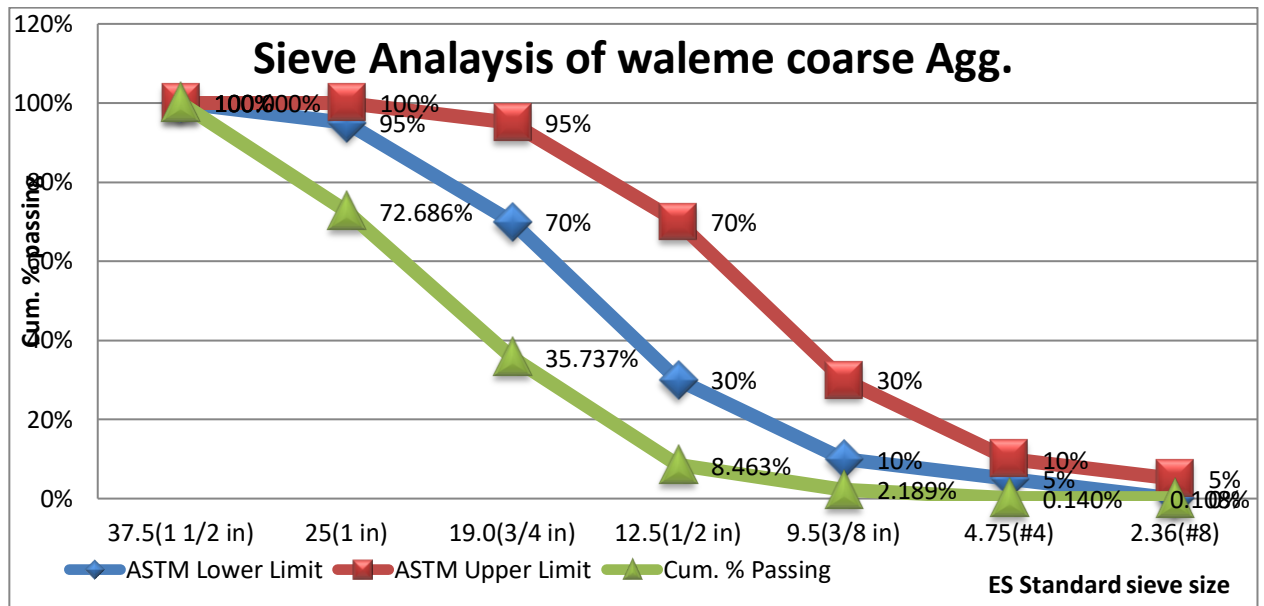


Figure 4.38 - Particle size distribution of waleme aggregate (trial 1)

➤ **Trial -2**

Table 4.10 Sieve Analysis Test Result for Waleme Coarse Aggregate (trial 2)

sieve Size(mm)	Wt of sample retained (g)	Wt. retained (%)	Cum. % retained	Cum. % pass	ESC.D3.201 limit		ASTM limits		Remark
					lower limit	lower limit	lower limit	upper limit	
37.5	0	0.000%	0.000%	100.000%	100%	100%	100%	100%	OK
25	701.2	28.084%	28.084%	71.916%	95%	100%	95%	100%	NO
19.0	892.3	35.738%	63.822%	36.178%	70%	95%	60%	95%	NO
12.5	679.6	27.219%	91.041%	8.959%	30%	70%	25%	60%	NO
9.5	179.2	7.177%	98.218%	1.782%	10%	30%	10%	25%	NO
4.75	44.5	1.782%	100.000%	0.000%	5%	10%	0%	10%	OK
2.36	0	0.000%	100.000%	0.000%	0%	5%	0%	5%	OK
pan	0	0.000%	100.000%	0.000%	-	-	-	-	-
Total	2496.8	100.000%							

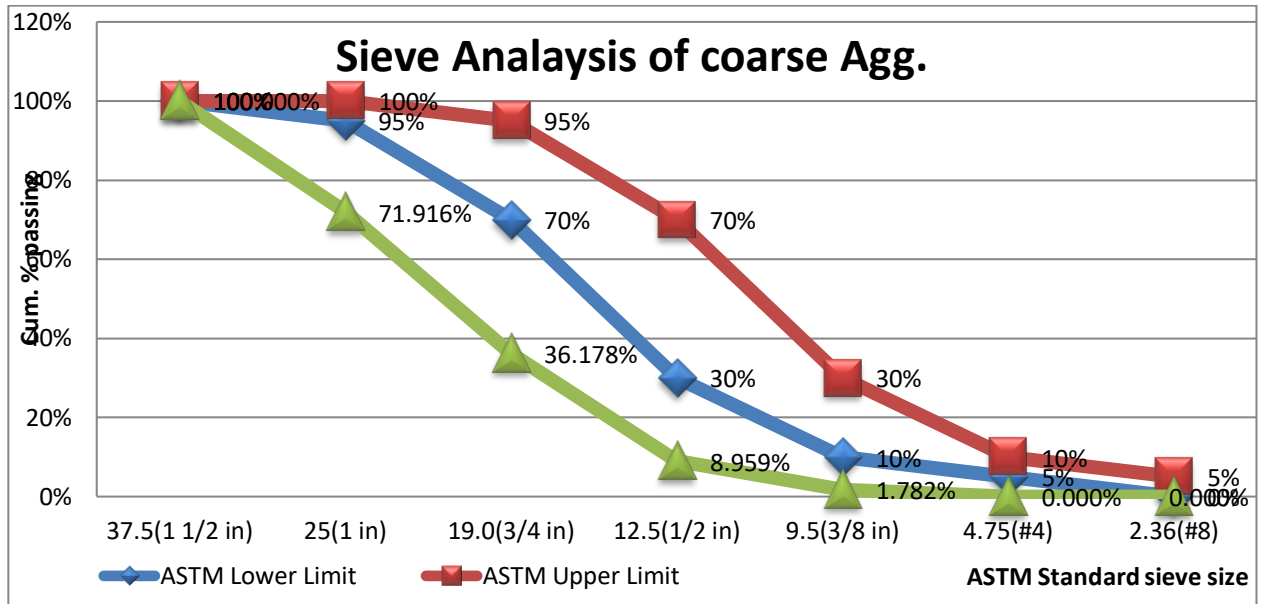


Figure 4.39 - Particle size distribution of waleme aggregate (trial 2)

B. Summary of other test result

The summary of other physical properties result of waleme’s aggregate is discussed below in the table 4.11, I have discussed the procedures and results in the appendix one.

Table 4.11 Summarized Test Results for Waleme Coarse Aggregate

Types of Test		Test Result	Remark
Unit Weight	Compacted	1270.4Kg/m ³	The result shows that the aggregate is not in the recommended limit (1280-1920kg/m³)
	Loose	1226.95Kg/m ³	
Bulk specific gravity	Oven-dry	2.38	The recommended relative density limit in (2.30 – 2.90) and waleme’s aggregate has 2.4 which is suitable.
	Saturated & Surface dry	2.40	
	Apparent	2.41	
Water Absorption Capacity		3.6 %	The recommended Absorption capacity limit ranges (0.5% – 4%) and waleme’s aggregate has 3.6% of Average Absorption capacity
Moisture Content		1.1%	The moisture content of waleme’s aggregate is 1.1% which is in the range (0.5 – 2%)

➤ **Discussion on Waleme Aggregate**

Waleme's aggregate has a gradation which is not as per the standard and it contains much coarser materials which affect the concrete production as it may be liable to segregation. The unit weight result which is lesser than the lower limit also shows that this aggregate is coarser enough and has higher voids in it and this is also a problem as it may require more paste to fill the voids when concrete is produced using this aggregate. The relative density of this aggregate is within the recommended limit (2.3 - 2.9). The moisture content of waleme's aggregate is also less than its absorption capacity ($1.1\% < 3.6\%$), since it has high absorption capacity, while using this aggregate the mixing water should be increased.

iii. **Mechisho Aggregate Production**

B. Sieve Analysis

The gradation of mechisho's aggregate is not in limit on 25mm and 19mm sieves of both standards. According to sieve analysis results shown in table 4.12 first trial and table 4.13 second trial, this aggregate is much coarser than it should be, with a higher amount of aggregate retained in 25mm, 19mm and 9.5mm sieve sizes.

➤ **Trial -1**

Table 4.12 Sieve Analysis Test Result for Mechisho Coarse Aggregate (trial 1)

sieve Size(mm)	Wt of sample retained (g)	Wt. retained (%)	Cum. % retained	Cum. % pass	ESC.D3.201 limit		ASTM limits		Remark
					lower limit	lower limit	lower limit	upper limit	
37.5	0	0.000%	0.000%	100.000%	100%	100%	100%	100%	OK
25	532.1	21.382%	21.382%	78.618%	95%	100%	95%	100%	NO
19.0	622.5	25.015%	46.397%	53.603%	70%	95%	60%	95%	NO
12.5	659.2	26.490%	72.887%	27.113%	30%	70%	25%	60%	OK
9.5	415.3	16.689%	89.576%	10.424%	10%	30%	10%	25%	OK
4.75	251.4	10.102%	99.679%	0.321%	5%	10%	0%	10%	OK
2.36	6.2	0.249%	99.928%	0.072%	0%	5%	0%	5%	OK
pan	1.8	0.072%	100.000%	0.000%	-	-	-	-	-
Total	2488.5	100.000%							

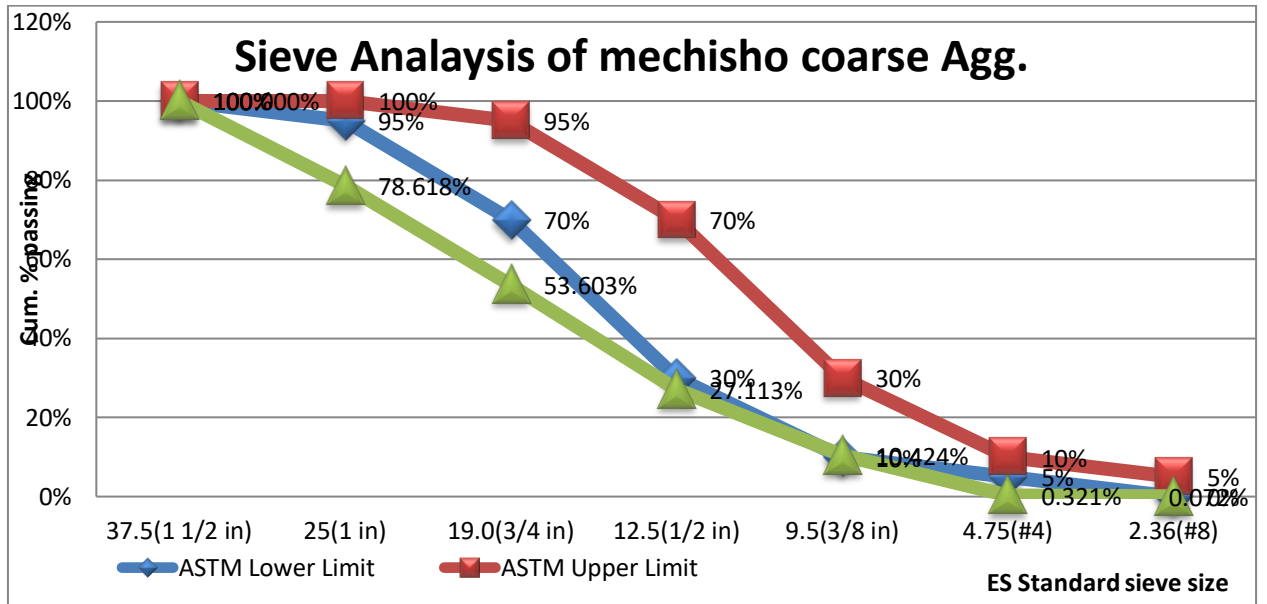


Figure 4.40 - Particle size distribution of Mechisho aggregate (trial 1)

➤ **Trial -2**

Table 4.13 Sieve Analysis Test Result for Mechisho Coarse Aggregate (trial 2)

sieve Size(mm)	Wt of sample retained (g)	Wt. retained (%)	Cum. % retained	Cum. % pass	ESC.D3.201 limit		ASTM limits		Remark
					lower limit	lower limit	lower limit	upper limit	
37.5	0	0.000%	0.000%	100.000%	100%	100%	100%	100%	OK
25	428.6	17.180%	17.180%	82.820%	95%	100%	95%	100%	NO
19.0	614.3	24.623%	41.803%	58.197%	70%	95%	60%	95%	OK
12.5	702.4	28.155%	69.958%	30.042%	30%	70%	25%	60%	OK
9.5	551.2	22.094%	92.051%	7.949%	10%	30%	10%	25%	NO
4.75	194.3	7.788%	99.840%	0.160%	5%	10%	0%	10%	OK
2.36	2.2	0.088%	99.928%	0.072%	0%	5%	0%	5%	OK
pan	1.8	0.072%	100.000%	0.000%	-	-	-	-	-
Total	2494.8	100.000%							

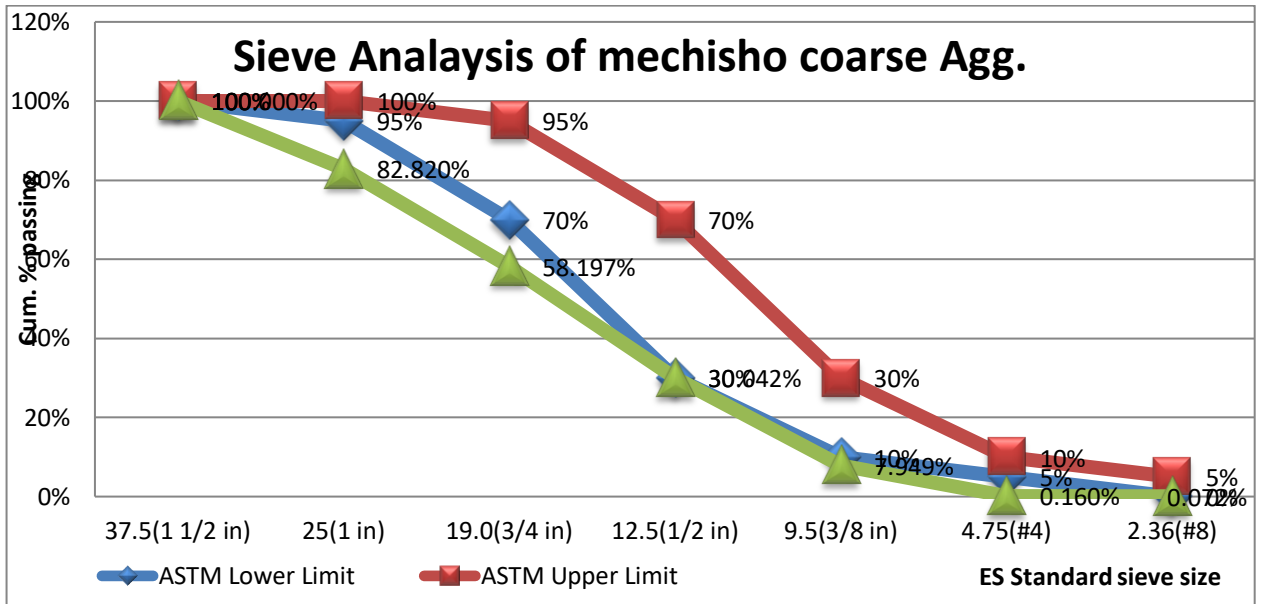


Figure 4.41 Particle size distribution of Mechisho aggregate (trial 2)

C. Summary of other test result

The summary of other physical properties result of mechisho’s aggregate is discussed below in the table 4.14, I have discussed the procedures and results in the appendix one.

Table 4.14 Summarized Test Results for Mechisho Coarse Aggregate

Types of Test		Test Result	Remark
Unit Weight	Compacted	1527.54Kg/m ³	The result shows that the aggregate is in the recommended limit (1280-1920kg/m³)
	Loose	1437.42Kg/m ³	
Bulk specific gravity	Oven-dry	2.28	The recommended relative density limit in (2.30 – 2.90) and mechisho’s aggregate has 2.31 which is suitable.
	Saturated & Surface dry	2.31	
	Apparent	2.37	
Water Absorption Capacity		3.97 %	The recommended Absorption capacity limit ranges (0.5% – 4%) and mechisho’s aggregate has 3.97% of Average Absorption capacity
Moisture Content		0.52 %	The moisture content of mechisho’s aggregate is 0.52% which is in the range (0.5 – 2%)
Fineness Modules		7.674	A coarse aggregate fineness module doesn’t affect the concrete mix design.

➤ **Discussion on Mechisho Aggregate**

Generally, mechisho's aggregate also has a gradation which is not in the limit of the standards and it contains much coarser materials. The unit weight result shows its suitable value for concrete making since the sample has fewer voids in it. The absorption capacity of mechisho's aggregate is very high and near to the highest limit which means the amount water requires in the concrete mix while using this aggregate is even more.

iv. Golla Aggregate Production

A. Sieve Analysis

The Golla Aggregate has a good gradation result as shown in the table 4.15 and 4.16 which indicates the sieve analysis result and the standard provided. In both trials of the sieve analysis test the samples were in the limit of the standards. The other properties results and procedures of Golla Aggregate are discussed in appendix one.

Trial -1

Table 4.15 Sieve Analysis Results for Golla Coarse Aggregate (trial 1)

sieve Size (mm)	Wt of sample retained (g)	Wt. retained (%)	Cum. % retained	Cum. % pass	ESC.D3.201 limit		ASTM(AASHTO) limits		Remark
					lower limit	lower limit	lower limit	upper limit	
37.5	0	0.000%	0.000%	100.000%	100%	100%	100%	100%	OK
25	32.41	1.306%	1.306%	98.694%	95%	100%	95%	100%	OK
19.0	89.62	3.612%	4.918%	95.082%	70%	95%	60%	95%	OK
12.5	991.3	39.953%	44.872%	55.128%	30%	70%	25%	60%	OK
9.5	1027.65	41.418%	86.290%	13.710%	10%	30%	10%	25%	OK
4.75	303.96	12.251%	98.541%	1.459%	5%	10%	0%	10%	OK
2.36	27.41	1.105%	99.645%	0.355%	0%	5%	0%	5%	OK
pan	8.8	0.355%	100.000%	0.000%	-	-	-	-	-
Total	2489.15	100.000%							

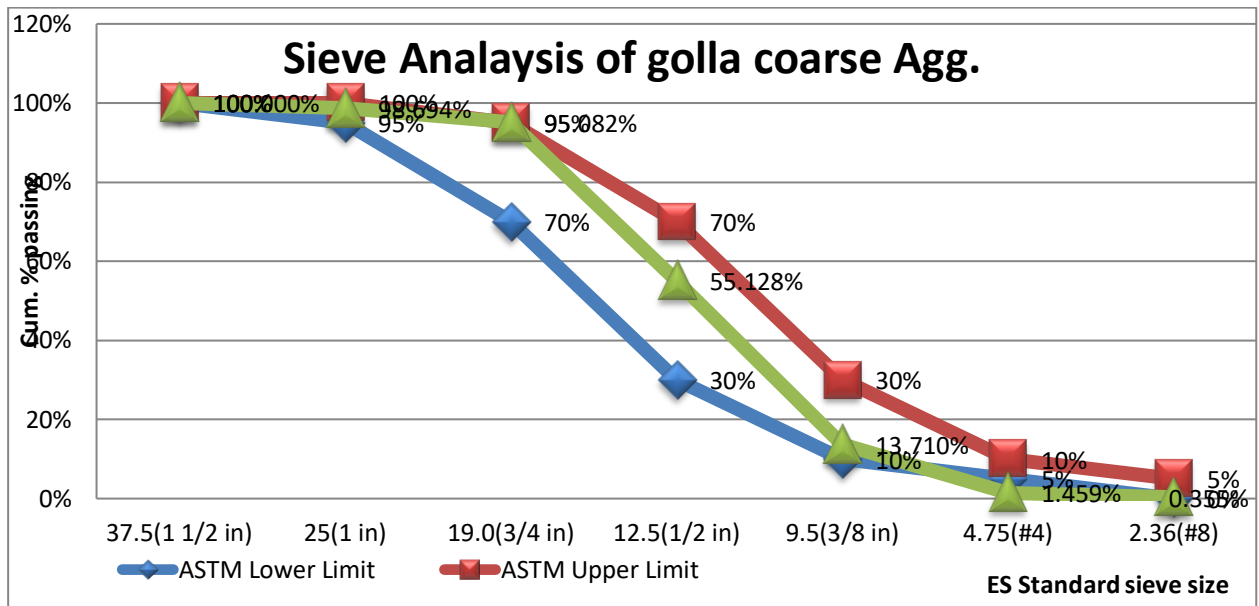


Figure 4.42 - Particle size distribution of Golla aggregate (trial 1)

➤ **Trial - 2**

Table 4.16 Sieve Analysis Results for Golla Coarse Aggregate (trial 2)

sieve Size (mm)	Wt of sample retained (g)	Wt. retained (%)	Cum. % retained	Cum. % pass	ESC.D3.201 limit		ASTM(AASHTO) limits		Remark
					lower limit	lower limit	lower limit	upper limit	
37.5	0	0.000%	0.000%	100.000%	100%	100%	100%	100%	OK
25	77.23	3.098%	3.098%	96.902%	95%	100%	95%	100%	OK
19.0	101.56	4.074%	7.173%	92.827%	70%	95%	60%	95%	OK
12.5	798.51	32.035%	39.208%	60.792%	30%	70%	25%	60%	OK
9.5	978.99	39.275%	78.483%	21.517%	10%	30%	10%	25%	OK
4.75	488.92	19.615%	98.098%	1.902%	5%	10%	0%	10%	OK
2.36	37.2	1.492%	99.590%	0.410%	0%	5%	0%	5%	OK
pan	10.22	0.410%	100.000%	0.000%	-	-	-	-	-
Total	2492.63	100.000%							

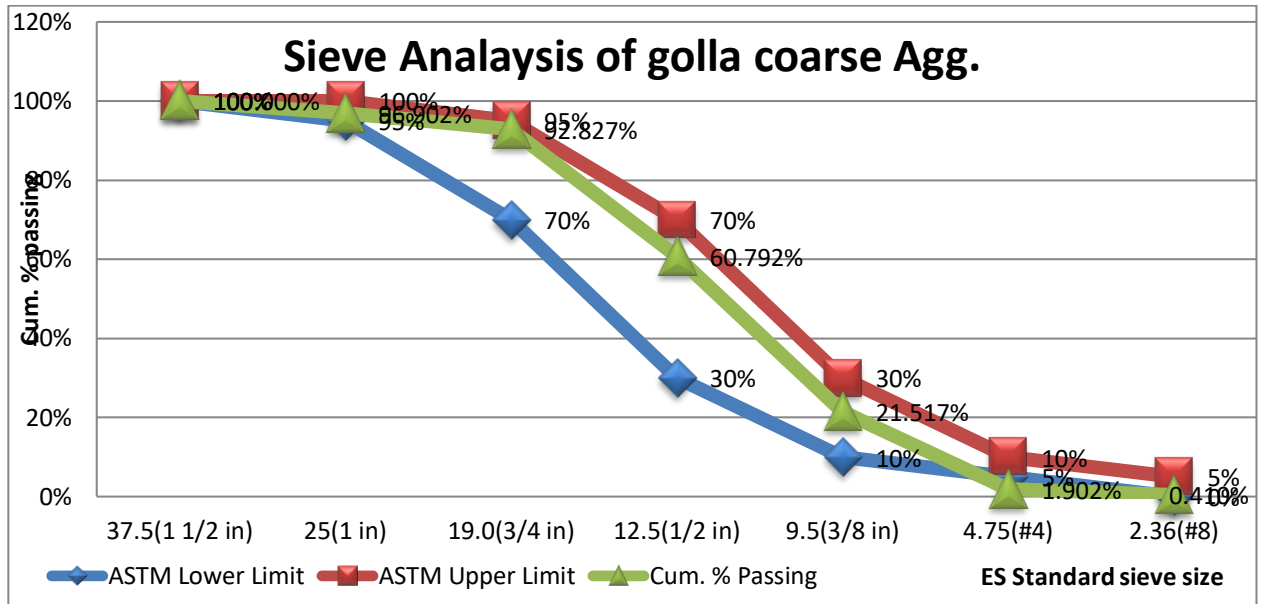


Figure 4.43 - Particle size distribution of Golla aggregate (trial 2)

B. Summary of other test result

The summary of other physical properties result of mechisho’s aggregate is discussed below in the table 4.17, I have discussed the procedures and results in the appendix one.

Table 4.17 Summarized Test Results for Golla Coarse Aggregate

Types of Test		Test Result	Remark
Unit Weight	Compacted	1521.17 Kg/m ³	The result shows that the aggregate is in the recommended limit (1280-1920kg/m³)
	Loose	1445.39 Kg/m ³	
Bulk specific gravity	Oven-dry	2.47	The recommended relative density limit in (2.30 – 2.90) and mechisho’s aggregate has 2.5 which is suitable.
	Saturated & Surface dry	2.50	
	Apparent	2.55	
Water Absorption Capacity		1.29%	The recommended Absorption capacity limit ranges (0.5% – 4%) and mechisho’s aggregate has 1.29% of Average Absorption capacity
Moisture Content		2.10%	The moisture content of mechisho’s aggregate is 0.52% which is in the range (0.5 – 2%)

➤ **Discussion on Golla Aggregate**

Golla's aggregate has the good gradation and it is according to the standard. Since, uniformly distributed size of aggregate make concrete production better, this aggregate is suitable in mixing and producing concrete. The unit weight result of this aggregate which is 1521.17 Kg/m³, show that the aggregate is within the recommended limit (1280-1920kg/m³). The higher the bulk density means the fewer the void in it and good gradation, which reduces the paste in concrete production. The specific gravity result 2.50 is also in the range (2.3 – 2.9) and suitable according to the standard provided. The property that needs a care is its moisture content 2.1% which is greater than the upper limit (0.5 – 2.0%). This affects the water cement ratio and the batching weight of aggregate. The higher the water content in the aggregate the lesser the mixing water required in concrete production.

4.2.2. Fine Aggregates

i. Gidabo Sand

A. Sieve Analysis

According to ASTM C33 and ES C D3.201, the gradation result of the Gidabo sand sample was out of range on 1.18 mm and 600 µm sieve size. The Sieve analysis result of Gidabo sand is shown below in Table 4.18 and Figure 4.44 for trial one and Table 4.19 and Figure 4.45 for trial two.

➤ **Trial one**

Table 4.18 Sieve Analysis Test Result for Gidabo sand (trial 1)

sieve Size mm	Wt of sample retained (g)	Wt. retained (g)	Cum. % retained	Cum. % pass	ASTM limits (AASHTO)		ES C D3.201 limit		Remark
					Lower	Upper	Lower	Upper	
9.5	0.000	0.000%	0.00%	100.000%	100%	100%	100%	100%	sieved off
4.75	1.500	0.300%	0.300%	99.700%	95%	100%	95%	100%	ok
2.36	3.60000	0.720%	1.021%	98.979%	80%	100%	80%	100%	ok
1.18	25.700	5.143%	6.164%	93.836%	50%	85%	50%	85%	NO
0.6	68.500	13.709%	19.873%	80.127%	25%	60%	25%	60%	NO
0.3	295.100	59.058%	78.931%	21.069%	10%	30%	10%	30%	ok
0.15	79.850	15.980%	94.911%	5.089%	0%	10%	2%	10%	ok
0.075	17.630	3.528%	98.439%	1.561%					
pan	7.800	1.561%	100.000%	0.000%					
Total	499.680		201.19%						

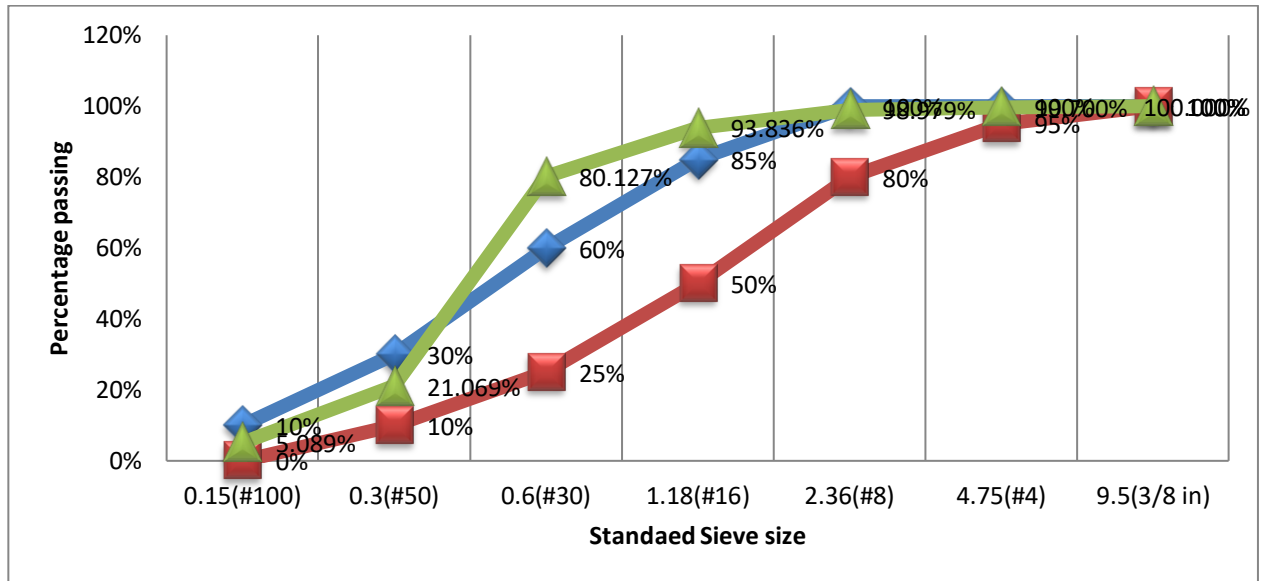


Figure 4.44 - size distribution of Gidabo sand (trial 1)

➤ **Trial two**

Table 4.19 Sieve Analysis Test Result for Gidabo sand (trial 2)

sieve Size mm	Wt of sample retained(g)	Wt. retained (g)	Cum. % retained	Cum. % pass	ASTM limits (AASHTO)		ES C D3.201 limit		Remark
					Lower	Upper	Lower	Upper	
9.5	0.000	0.000%	0.00%	100.000%	100%	100%	100%	100%	sieved off
4.75	2.010	0.404%	0.404%	99.596%	95%	100%	95%	100%	ok
2.36	3.81000	0.765%	1.169%	98.831%	80%	100%	80%	100%	ok
1.18	31.200	6.266%	7.435%	92.565%	50%	85%	50%	80%	NO
0.6	77.500	15.565%	23.000%	77.000%	25%	60%	25%	50%	NO
0.3	279.100	56.053%	79.053%	20.947%	10%	30%	10%	25%	ok
0.15	64.500	12.954%	92.007%	7.993%	0%	10%	2%	10%	ok
0.075	31.000	6.226%	98.233%	1.767%					
pan	8.800	1.767%	100.000%	0.000%					
Total	497.920								

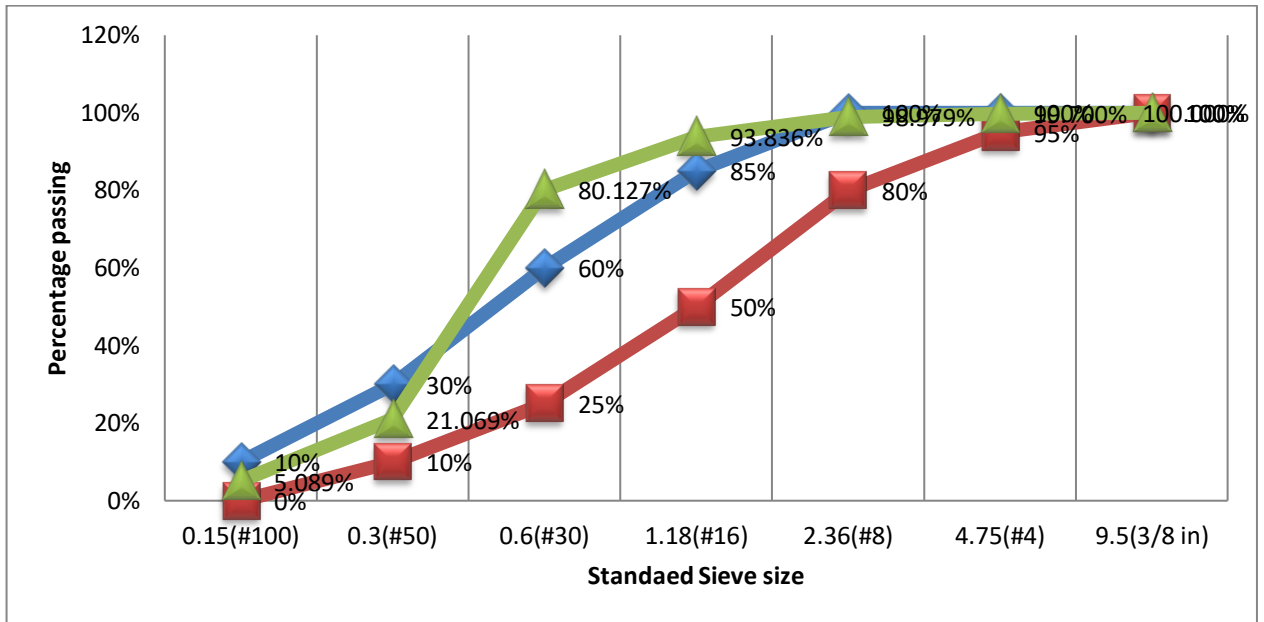


Figure 4.45 - Particle size distribution of Gidabo sand (trial 2)

In both trials the gidabo sand is out of range in ASTM and Ethiopian standard in sieve 1.18mm and 600 μ m. more percent sand passes these two sieve sizes means it contains finer sand.

B. Zoning of Gidabo Sand

The average cumulative percent sand pass should be taken to determine the zoning of Gidabo Sand. Table 4.20 shows the average cumulative percentage of passing sand in each sieve.

Table 4.20 Average Cumulative Percentage of pass of Gidabo sand

Sieve Size Mm(In)	Cum. % Pass Trail-1	Cum. % Pass Trail-2	Ave.
9.5(3/8 in)	100.00%	100.00%	100.000%
4.75(#4)	99.70%	99.60%	99.648%
2.36(#8)	98.98%	98.83%	98.905%
1.18(#16)	93.84%	92.57%	93.201%
0.6(#30)	80.13%	77.00%	78.564%
0.3(#50)	21.07%	20.95%	21.008%
0.15(#100)	5.09%	7.99%	6.541%
0.075(#200)	1.56%	1.77%	1.664%
Pan	0.00%	0.00%	0.000%

Based on BS specification as shown in Table 4.21 and figure 4.46 below, the grading of the Gidabo sand sample is under zone three which indicate it is moderate finer Sand.

Table 4.21 Zoning of Gidabo sand

Sieve Size (mm)	Equivalent BS Sieve	Ave. Cum% passing	Percentage passing (%)							
			Zone-1		Zone-2		Zone-3		Zone-4	
			min	Max	min	Max	min	Max	min	Max
10	3/8 in	100.000%	100	100	100	100	100	100	100	100
4.75	3/16 in	99.648%	90	100	90	100	90	100	95	100
2.36	# 7	98.905%	60	95	75	100	85	100	95	100
1.18	#14	93.201%	30	70	55	90	75	100	90	100
0.6	#25	78.564%	15	34	35	59	60	79	80	100
0.3	#52	21.008%	5	20	8	30	14	40	15	50
0.15	#100	6.541%	0	10	0	10	0	10	0	15
0.075	#200	1.664%								

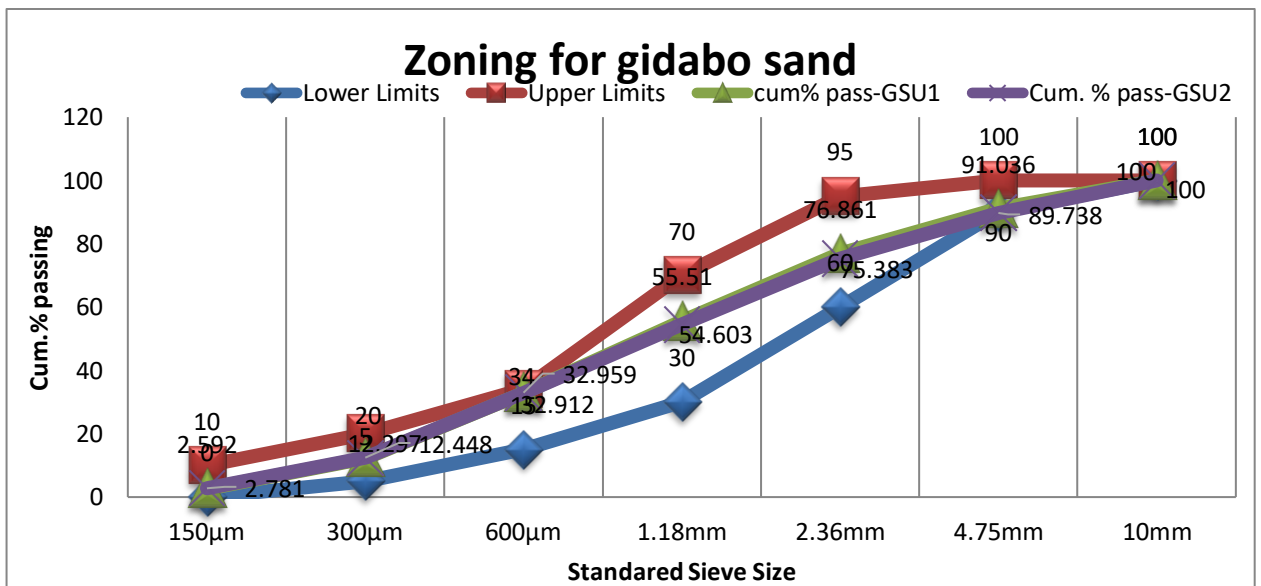


Figure 4.46 - Zoning of Gidabo sand

C. Summary of Other results

A detailed sieve analysis of the Gidabo sand and the results for other properties including particle size distribution is found in appendix-1.

Table 4.22 Summarized test results for Gidabo sand

Types of Test		Test Result	Remark
Unit Weight`	Compacted	1741.846Kg/m ³	The result shows that the aggregate is within the recommended limit (1200-1750kg/m³)
	Loose	1628.582Kg/m ³	
Bulk specific gravity	Oven-dry	2.57	The recommended relative density for fine aggregate ranges (2.6 – 2.8) and gidabo sand has 2.6
	Saturated & Surface dry	2.60	
	Apparent	2.63	
Water Absorption Capacity		0.92%	The recommended Absorption capacity limit ranges (0.2% – 2%) and the gidabo sand has 0.92% .
Moisture Content		2.01%	The moisture content of gidabo sand is 2.01% which is in the range (2-6%)
Fineness Modules		2.06	Fineness modulus of gidabo sand is less than the ranges (2.2 - 3.2) which indicate that it is finer sand.
Silt/Clay content		5.73%	The maximum amount of silt allowed in Ethiopian standard is 6%
coefficient of uniformity (Cu)		5.485	> 5, well graded according to uniformity coefficient
coefficient of curvature (Cc)		0.840	< 1, out of well graded limit according to curvature coefficient
Zone		III	Medium to fine sand
Organic impurities test		Fail	High content of organic impurity

➤ Discussion on Gidabo Sand

The gidabo sand has suitable result of unit weight around 1741.846Kg/m³ and it's containing similarly graded materials. This sand also has good bulk density and bulk specific gravity results. The specific gravity of suitable fine aggregates varies from 2.6 to 2.8. Hence the sample having bulk specific gravity of 2.6 is suitable for concrete. The water absorption and moisture content results are also in the recommended limits. Fineness

Modules of the Gidabo sand sample is 2.06 this can be interpreted that the Gidabo sand fine sand since it has the fineness modulus less than 2.20. However, depending upon their size, sand can be classified as coarse sand when a fineness modulus is between 2.90 to 3.20; medium sand with a fineness modulus of 2.60 to 2.90 and; fine sand with a fineness Modulus of 2.20 to 2.60 and Sand with fineness modulus less than 2.2 is very fine sand. The coefficient of uniformity (Cu) and coefficient of curvature (Cc) are 5.485 and 0.840 respectively; however the sand sample was unsatisfactory the criteria for both Cu and Cc values, even-though more approximate to the value that provided in Table 2.5 and Table 2.6 though the Gidabo sand sample was well graded and also gap-graded sand sample.

ii. Kilkile Sand

The same procedures had been followed in investigating the kilkile sand too the sieve analysis was performed and zoning of the sand also investigated. As table 4.23 shown below the kilkile sand is categorized under zone one.

Table 4.23 Zoning of Kilkile Sand Sample

Sieve Size (mm)	Equivalent BS Sieve	Ave. Cum% passing	Percentage passing (%)							
			Zone-1		Zone-2		Zone-3		Zone-4	
			min	Max	min	Max	min	Max	min	Max
10	3/8 in	100.0	100	100	100	100	100	100	100	100
4.75	3/16 in	89.7	90	100	90	100	90	100	95	100
2.36	# 7	75.6	60	95	75	100	85	100	95	100
1.18	#14	52.3	30	70	55	90	75	100	90	100
0.6	#25	25.5	15	34	35	59	60	79	80	100
0.3	#52	6.6	5	20	8	30	14	40	15	50
0.15	#100	1.4	0	10	0	10	0	10	0	15
0.075	#200	0.5								

Table 4.24 Summarized Test Results for Kilikile Sand

Types of Test		Test Result	Remark
Unit Weight`	Compacted	1599.299Kg/m ³	The result shows that the aggregate is within the recommended limit (1200-1750kg/m³)
	Loose	1510.086Kg/m ³	
Bulk specific gravity	Oven-dry	2.59	The recommended relative density for fine aggregate ranges (2.6 – 2.8) and kilikile sand has 2.68
	Saturated & Surface dry	2.68	
	Apparent	2.74	
Water Absorption Capacity		2.93%	The recommended Absorption capacity limit ranges (0.2% – 2%) and the kilikile sand has 2.93% .
Moisture Content		1.40%	The moisture content of kilikile sand is 1.40% which is not in the range (2-6%)
Fineness Modules		3.46	Fineness modulus of kilikile sand is greater than the ranges (2.2 - 3.2) which indicate that it is coarser sand.
Silt/Clay content		3.52%	The maximum amount of silt allowed in Ethiopian standard is 6%
coefficient of uniformity (Cu)		4.46	> 5, uniformly graded according to uniformity coefficient
coefficient of curvature (Cc)		0.878	< 1, out of well graded limit according to curvature coefficient
Zone		I	Coarser sand
Organic impurities test		Pass	Acceptable organic impurity content

➤ **Discussion on Kilikile Sand**

A detailed sieve analysis of the Kilikile sand was found in appendix-1 and the grading curve was showed in figure A1.8 and A1.9 according to ASTM and Ethiopian standard grading requirement respectively. The kilikile sand has suitable result of unit weight around 1599.29 Kg/m³ and its containing similarly graded materials. This sand also has good bulk density and bulk specific gravity results. The specific gravity of suitable fine aggregates varies from 2.6 to 2.8. Hence the sample having bulk specific gravity of 2.68 is suitable for concrete. The water absorption and moisture content results are also in the recommended

limits but higher absorption than moisture content. Fineness Modulus of the kilkile sand sample is 3.464, which is greater than 3.2 for this reason the sample was unsatisfactory the classification that shown in Table 2.4, on the other hand this show that the sand sample was the coarsest sand sample in addition to this, the fineness modulus value of the kilkile sand showed that the sand type was more coarsest than the gidabo sand. The Cu and Cc values are 4.464 and 0.878 respectively; however the sand sample was unsatisfactory the criteria that provided in Table 2.5 and Table 2.6 due to this, the kilkile sample was poorly graded and also gap-graded sand sample.

iii. Gollelicha Sand

Table 4.25 Zoning of Gollelicha Sand Sample

Sieve Size (mm)	Equivalent BS Sieve	Ave. Cum.% passing	Percentage passing (%)								
			Zone-1		Zone-2		Zone-3		Zone-4		
			min.	Max.	min.	Max.	min.	Max.	min.	Max.	
10	3/8 in	100.0	100	100	100	100	100	100	100	100	100
4.75	3/16 in	99.8	90	100	90	100	90	100	95	95	100
2.36	# 7	99.1	60	95	75	100	85	100	95	95	100
1.18	#14	95.7	30	70	55	90	75	100	90	90	100
0.6	#25	80.8	15	34	35	59	60	79	80	80	100
0.3	#52	17.5	5	20	8	30	14	40	15	15	50
0.15	#100	2.9	0	10	0	10	0	10	0	0	15
0.075	#200	0.9									

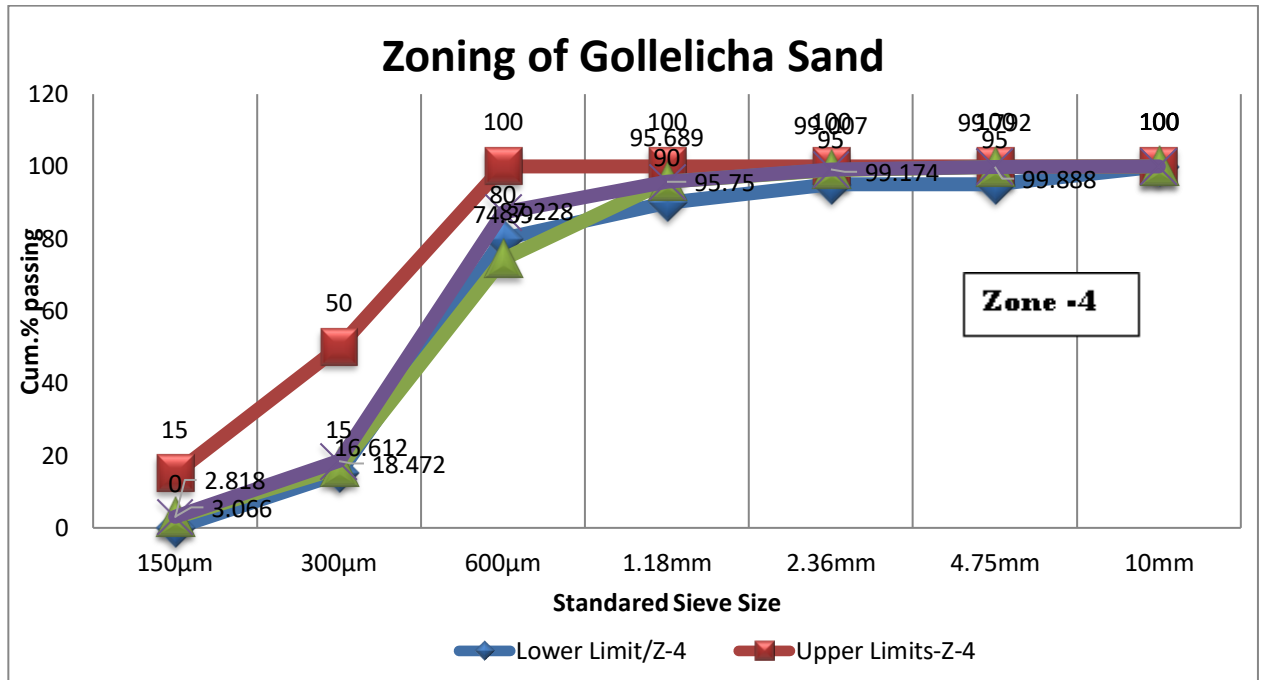


Figure 4.47 - zoning chart for gollelicha sand according to BS Limitation

Table 4.26 Summarized Test Results for Gollelicha Sand

Types of Test		Test Result	Remark
Unit Weight`	Compacted	1347.129Kg/m ³	The result shows that the aggregate is within the recommended limit (1200-1750kg/m³)
	Loose	1277.009Kg/m ³	
Bulk specific gravity	Oven-dry	2.37	The recommended relative density for fine aggregate ranges (2.6 – 2.8) and gollelicha sand has 2.53
	Saturated & Surface dry	2.53	
	Apparent	2.79	
Water Absorption Capacity		3.34%	The recommended Absorption capacity limit ranges (0.2% – 2%) and the gollelicha sand has 3.34% .
Moisture Content		2.58%	The moisture content of gollelicha sand is 2.58% which is not in the range (2-6%)
Fineness Modules		1.893	Fineness modulus of gollelicha sand is less than the ranges (2.2 - 3.2) which indicate that it is very finer sand.
Silt/Clay content		5.63%	The maximum amount of silt allowed in Ethiopian standard is 6%

coefficient of uniformity (Cu)	2.27	< 5, uniformly graded according to uniformity coefficient
coefficient of curvature (Cc)	1.18	>1, well graded according to curvature coefficient
Zone	VI	finer sand
Organic impurities test	Fail	High content of organic impurity

Fineness Modules(FM) of Gollelicha sand sample was 1.893 that is less than 2.0 for this reason the sample was unsatisfactory the classification that shown in previous chapter two in Table 2.4, on the other hand this show that the sand sample was the Finest sand sample. A detailed sieve analysis of the Gollelicha sand was found in appendix-1 in Table A1.7 and the grading curve was showed in Figure A1.6 and A1.7 according ASTM and BS grading requirement respectively.

➤ **Discussion on Gollelicha Sand**

The gollelicha sand has suitable result of unit weight around 1347.12 Kg/m³ and its containing similarly graded materials. The specific gravity of suitable fine aggregates varies from 2.6 to 2.8 but this sand has 2.52 which is less than the minimum. The water absorption capacity of this sand is more than the limit and using this sand without considering its absorption capacity which affects the concrete strength. Fineness Modules of the gollelicha sand sample is 1.89, which is less than 2.2 for this reason the sample was unsatisfactory the classification that shown in Table 2.4, on the other hand this show that the sand sample was the finest sand sample in addition to this, the fineness modulus value of the gollelicha sand showed that the sand type was more finer than the gidabo sand as well as kilkile sand. The Cu and Cc values 1.18 respectively; however the sand sample was unsatisfactory the criteria that provided in Table 2.5 and Table 2.6 due to this, the gollelicha sample was poorly graded and also gap-graded sand sample

4.2.3. Concrete compressive strength

To justify the effects of these properties of aggregates on concrete mix and its compressive strength, I designed a concrete mix, cast and investigate its compressive strength. To do so, I chooses the coarse aggregates and two fine aggregates which are one having better properties and the other one with less quality comparatively. The same true for fine aggregates and the mixing is done by combining the two better coarse and fine aggregates (the wenago coarse aggregate and the kilkile fine aggregate) together which I call it concrete mix one and the other which is concrete mix two is formed using the two less quality coarse and fine aggregates (the waleme coarse aggregate and the golelicha fine aggregate).

4.2.3.1. Mix design

In this section the concrete mix design process is discussed. The detail of the mix design calculation process ids discussed in the appendix two.

General Assumptions

- Mix designing is using ACI method
- Required slump = 50mm
- Allowable failure rate 5%
- Cement is dangote cement grade 42.5

1) Concrete Mix One

This is a concrete mix is produced using wenago coarse aggregate and kilkile fine aggregate.

a. Materials Property

Table 4.27 Materials property for concrete mix one

Mix - One			
Coarse Aggregate		Fine Aggregate	
Wenago Aggregate		Kilkile Sand	
Properties	Result	Properties	Result
Nominal maximum size	25mm	Unit weight	1599.84 Kg/m ³
Unit weight	1641.57 Kg/m ³	Fineness modulus	3.46
Specific gravity	2.49	Specific gravity	2.59
Absorption capacity	1.77%	Absorption capacity	2.93%
Moisture content	0.88%	Moisture content	1.40%

b. Proportioning of Ingredients

Table 4.28 proportioning of ingredients for concrete mix one

Ingredient	Cement Kg/m³	Water Kg/m³	Fine agg. Kg/m³	Coarse agg. Kg/m³
Quantity(kg/m³)	400.89	180	500.74	1026
For 0.07m³ trial mix	28.06	12.6	35.05	71.82

2) Concrete Mix Two

This concrete mix is produced using walleme coarse aggregate and gollelicha sand.

a. Materials property

Table 4.29 Materials property for concrete mix two

Mix - Two			
Coarse Aggregate		Fine Aggregate	
Waleme Aggregate		Gollelicha Sand	
Properties	Result	Properties	Result
Nominal maximum size	25mm	Unit weight	1347.12 Kg/m ³
Unit weight	1270.44 Kg/m ³	Fineness modulus	1.893
Specific gravity	2.40	Specific gravity	2.53
Absorption capacity	3.6%	Absorption capacity	3.34
Moisture content	1.1%	Moisture content	2.58%

b. Proportioning

Table 4.30 proportioning of ingredients for concrete mix two

Ingredient	Cement (Kg)	Water (Kg)	Fine agg. (Kg)	Coarse agg. (Kg)
Quantity(kg/m³)	400.89	180	540.2	794.3
For 0.07m³ trial mix	28.06	12.6	37.81	55.60

4.3.2 Compressive strength results

After mixing and preparing, the concrete cubes were cured by immersion in water in the curing tank for 28 day at a temperature of $23 \pm 1^\circ\text{C}$ for curing to take place until the testing age was reached as shown in figure 3.16 in the appendix 3. The compressive strength test results are discussed in table 4.31

Table 4.31 compressive strength test results

Mix sample	Sample specimen	Weight of sample (Kg)	Maximum load (KN)	Compressive strength (MPa)
7th Days Compressive Strength Results				
Concrete One	Sample - 1	8.41	722.22	32.19
	Sample - 2	8.29	733.91	32.78
	Sample - 3	8.37	700.88	31.28
	Average			32.08
Concrete Two	Sample - 1	8.38	581.44	24.20
	Sample - 2	8.42	597.29	25.31
	Sample - 3	8.29	589.10	24.52
	Average			24.67
28th Days Compressive Strength Results				
Concrete one	Sample - 1	8.28	788.26	35.81
	Sample - 2	8.38	759.39	33.92
	Sample - 3	8.33	772.64	34.84
	Average			34.85
Concrete two	Sample - 1	8.49	637.23	28.31
	Sample - 2	8.41	666.27	29.34
	Sample - 3	8.39	619.26	27.56
	Average			28.40

➤ Discussion of compressive strength test results

The result shows that the compressive strength of concrete one (wenago coarse aggregate and kilikile fine aggregate) is better than concret two (waleme coarse aggregate and the gollelicha fine aggregate). As the result indicated concrete mix one has the concrete compressive strength of 34.85MPa in the 28th day which greater than concrete mix two

which has 28.4MPa 28th day compressive strength. This is due to those unsatisfactory properties of the ingredients.

4.2.4. Hollow Concrete Block

4.2.4.1. Compressive strength test

A. Results and analysis

The compressive strength test results shows that all HCB produced and investigated in this research are unsatisfactory of the standard provided by Ethiopian standard [ES.C.D3.301] which describes HCB of class should have the strength of 2N/mm² for an average of 6 samples and 1.8N/mm². The maximum compressive strength result is 1.17N/mm² of an average strength from Hibret HCB and the minimum is 0.6N/mm² from Zemenu HCB.

Table 4.32 Compressive Strength Test Result of Zemenu HCB (20cm)

Sample No.	Dimensions (cm)			Area (mm ²)	Max. Load (KN)	Compressive strength (MPa)	Remark
	L	W	H				
1	400	200	200	39960	32.4	0.81	Failed
2	400	200	200	39960	29.3	0.73	Failed
3	400	200	200	39960	27.1	0.67	Failed
4	400	200	200	39960	27.0	0.67	Failed
5	400	200	200	39960	30.8	0.77	Failed
6	400	200	200	39960	31.4	0.78	Failed
Mean						0.73	Failed

B. Summary of compressive strength results

All the results of compressive strength test for each of the production sites in type of products available in the site are discussed in the Appendix including the calculation used. Here below I tried to summarize all the results of compressive strength test for all production sites in the table 4.33

Table 4.33 Summary of Compressive Strength Test Result of All HCB Sites

Production site	Product size (cm)	Average compressive strength result (N/mm ²)	Ethiopian standard limits [ES.C.D3.301]		Remark
			Average (N/mm ²)	Individual (N/mm ²)	
Zemenu HCB	20	0.73	2	1.8	Failed
	15	0.60	2	1.8	Failed
Walleign HCB	20	0.89	2	1.8	Failed
	15	0.90	2	1.8	Failed
	10	0.94	2	1.8	Failed
Hibret HCB	20	1.17	2	1.8	Failed
	15	1.1	2	1.8	Failed
	10	1.15	2	1.8	Failed
Berta HCB	20	0.86	2	1.8	Failed
	15	0.85	2	1.8	Failed
Chefe HCB	20	1.05	2	1.8	Failed
	15	1.04	2	1.8	Failed

4.2.4.2. Absorption capacity

The absorption capacity of the blocks in each production site samples has been investigated and the result shows that all the blocks satisfies the recommended value by Ethiopian standard which is 290kg/m³ for non-loading hollow blocks in percent 25%. From the investigated HCB sites Walleign HCB site has the highest water absorption value 22.53% and the lowest water absorption capacity is from Berta HCB site. Table 4.34 below, shows the absorption capacity results of all HCB production site investigated.

Table 4.34 Summary of Water Absorption Test Result of All HCB Sites

HCB production site	Water absorption, kg/m ³	Water absorption, percent (%)
Walleign HCB	166.48	22.53
Hibret HCB	129.59	18.12
Zemenu HCB	151.86	20.18
Berta HCB	158.18	13.31
Chefe HCB	180.66	19.26

4.2.4.3. Block Density

The density of blocks of each production sites in this research has been investigated using the procedure provided in the standards. From the results we can see that all HCB investigated are failed to fulfill the standard in [20]. The maximum block density is 668kg/m³ from Hibret HCB of 10cm. the result of Hibret HCB production site is discussed below in table 4.35

Table 4.35 Block Density of Hibret HCB

Production site	Products size (cm)	Volume (cm ³)	Mass (kg)	Density (kg/m ³)	Ethiopian Standard ES 596:2001 (Kg/m ³)	Remark	
Hibret HCB	20	S-1	15600	9.972	639.23	900-1200	Failed
		S-2	16000	10.231	639.43	900-1200	Failed
		S-3	16000	10.924	682.75	900-1200	Failed
		Average			653.80	900-1200	Failed
	15	S-1	12000	8.01	667.50	900-1200	Failed
		S-2	12000	7.94	661.67	900-1200	Failed
		S-3	12000	7.66	638.34	900-1200	Failed
		Average			655.83	900-1200	Failed
	10	S-1	8000	5.21	651.25	900-1200	Failed
		S-2	8400	5.75	684.52	900-1200	Failed
		S-3	8000	5.36	670.00	900-1200	Failed
		Average			668.59	900-1200	Failed

All the other HCB production sites result is discussed in Appendix part. But the summarized result of each site according to their product had shown below in table 4.36

Table 4.36 Summary of Block Density Result of All HCB Sites

Production site	Product size (cm)	Average Block Density (kg/m ³)	Ethiopian standard limits [ES.C.D3.301] (kg/m ³)	Remark
Zemenu HCB	20	536.41	900 - 1200	Failed
	15	528.11	900 - 1200	Failed
Wallelign HCB	20	633.20	900 - 1200	Failed
	15	641.08	900 - 1200	Failed
	10	638.55	900 - 1200	Failed
Hibret HCB	20	653.80	900 - 1200	Failed
	15	655.83	900 - 1200	Failed
	10	668.59	900 - 1200	Failed
Berta HCB	20	578.32	900 - 1200	Failed
	15	591.74	900 - 1200	Failed
Chefe HCB	20	621.21	900 - 1200	Failed
	15	218.89	900 - 1200	Failed

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

The research carried out has shown some of the problems associated with the production process and quality of Aggregates and HCB produced in Gedeo zone and attempt is made to show the impact of improper quality control practice on the quality of Aggregate and hollow concrete block productions. The following conclusions and recommendations are drawn out from the investigation undertaken on the Aggregate and HCB production sites and their products.

5.1. CONCLUSION

Aggregates

- Based on my observation to different sites, aggregate production method of most sites in Gedeo zone is too back ward and does not supported with professional personals. Due to this in most of production plants the process is not as per the scientific standard and not modern which as the laboratory results shown affect the property of aggregates, especially the gradation of aggregates.
- The equipments for aggregate crushing used in the most plants is very old and most of the time not working and affect the production of consistent and quality products to the customers, which are compatible with the standard requirements.
- Among the physical properties that investigated for each of the products, the gradation of aggregate of most production plants is not as the standard. Beside the gradation other properties of the aggregates indicate that most of the products are good quality.
- No laboratory test is performed for the products in all aggregate production sites to check that if their product fulfills the standard required or not.
- The better the production process implemented the better quality aggregate is produced and after all the concrete produced with this materials has the better compressive strength result. On the other hand with those unsatisfactory production processes the products also has less quality and affect the concrete strength.
- The accesses road to major quarry sites is deteriorated and it is difficult to get access by truck especially during rainy season.
- In most aggregate production sites the practice of handling products is with Less care and no proper demarcation between different sizes of aggregates are absent in the aggregate

production plants. In all aggregate production plants, the ground for storing and stockpiling are not well prepared and protected from dust and other foreign substances.

- No periodic check from the governing body, so no checking if the production process is as per the standard or not.
- All sand sources of Gedeo zone are river bed sand which is excavated and stored using labor force. Since poor handling of the sand the quality is also weak because of its exposure to the contamination and easily combined with the surrounding soil.
- Most of the fine aggregates in Gedeo zone are highly finely graded which is out of the standard and affect the strength of concrete produced using these sand on by their own.
- The silt content of natural sand from river bed is too high to satisfy Ethiopian standard and other literature recommendation and also almost all of the samples failed to pass the organic impurity test.
- The source of fine aggregate were from river and sand deposit areas that most of the suppliers do not take care of quality and proper handling during supply.

Hollow Concrete Block

- Materials such as aggregates, cement and water for HCB production are observed on the sites selected for investigation are not passed through sufficient tests. In addition to this, the products also are not passed through necessary tests.
- HCB producers follow nominal mix procedure for proportioning of ingredients. Most of the producers are producing to meet class C category but those blocks not conform Ethiopian standard EC 596: 2001 class C category
- During observation, HCB producer's follows hand mixing method which affects the mixing proportion and the expenditure incurred on materials goes waste if the process is not taken care of.
- All the production site produces class C HCB permanently, other grades like class B and A and also HCB with size 10cm and 15cm as well as ribbed slab are produced only if they get order. This make impossible to investigate these HCB products.
- In almost all HCB production sites the compaction and vibration process is unsatisfied of the standard which is at least 1 minute and all HCB production sites had been implementing less than a minute in some sites even less than 30 second vibration time.

- Fine and coarse aggregates are placed adjacent to each other, so that there is a tendency of mixing of fine with coarse aggregates, and may be used without appropriate proportioning.

5.2. RECOMMENDATION

Aggregates

- Selection, testing and handlings of construction materials are important element to ensure the quality of products especially in the production of concrete as well as HCB, the ingredients has to be properly investigated since these two materials are produced by mixing different ingredients and the quality of each has their own impact.
- In Ethiopian construction industry necessary attention has not been given for aggregate quality, handling and standardization. The trend in our construction industry attempts to produce specified concrete by increasing cement content, which is uneconomical. Aggregate is purchased from trucks and nobody worries about standardization.
- Aggregate, both fine and coarse, identification, quarrying, storage and handling should be done professionally. In addition, the production processes should be evaluated by the government before licensing and proper and periodic check should be implemented to improve the quality of aggregate.
- Aggregate producers should give proper attention in producing consistent and quality products to the customers, which are compatible with the standard requirements. The producers should also be able to guarantee the quality of their products satisfying the required relevant standards.
- Careful handling of aggregates, strong clean hard base and proper demarcation between different sizes of aggregates are absent in the aggregate production plants.
- The silt content of natural sand from river bed is too high to satisfy Ethiopian standard and other literature recommendation. It is possible to reduce the silt content and also the impurities by using a proper handling mechanism and store on the place with no exposure to soil. It also possible to satisfy Ethiopian standards and other recommendation by washing the fine aggregate and blending different sands from different sources.
- The gradation of coarse aggregate and fine aggregate investigated in this research are mostly out of the standards; hence blending of aggregate should be practiced until the recommended amount of aggregate in the required size is achieved.

Hollow concrete block

- The materials property used in the production of HCB should be investigated and prepare a proper mix design based on the standard recommended. Test also should be done for the HCB they produce if they fulfill the standard or not and to come up with best quality materials.
- The production process of HCB should be done on the controlled manner and a care should take in each stage of the production process. Less curing and less vibration are among the problems in my observation which affects the strength of HCB produced.
- The addition of the soil like material called “bole” in the HCB production is practiced in Gedeo zone and its property should be studied.
- Fine aggregate, coarse aggregates, komiche and Bole are placed adjacent to each other, so that there is a tendency of mixing of fine with coarse aggregates, and other ingredients and may be used without appropriate proportioning.

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APPENDIX ONE

Property Investigation Results

1. Coarse Aggregate

1.1. Unit weight

1.1.1. Compacted Unit weight and Loose Unit Weight

For Maximum Size of coarse aggregate 37.5mm

Cylinder have –height (h) =30cm and Diameter (D) =25cm

$$A = \frac{\pi D^2}{4} \qquad V=A*h$$

Table A1- 1: Compacted and Loose Unit Weight Coarse Aggregate

Crushing site	Unit weight test	Average result of two samples (Kg/m ³)
Wenago crushing site	Compacted unit weight	1641.57
	Loose unit weight	1535.79
Waleme crushing site	Compacted unit weight	1270.40
	Loose unit weight	1226.95
Mechisho crushing site	Compacted unit weight	1527.54
	Loose unit weight	1437.42
Golla crushing site	Compacted unit weight	1521.17
	Loose unit weight	1445.39

1.2. Specific gravity and Absorption Capacity

➤ **Bulk specific gravity:**

$$Bulk\ Spe.gra = \left[\frac{A}{(B - C)} \right] \dots\dots\dots Equ.3A$$

➤ **Bulk specific gravity (saturated surface dry basis):**

$$Bulk\ Spe.gra = \left[\frac{B}{(B - C)} \right] \dots\dots\dots Equ.4A$$

➤ **Apparent specific gravity**

$$Apparent\ Specific\ gravity = \left[\frac{A}{(A - C)} \right] \dots\dots\dots Equ.5A$$

➤ **Absorption capacity:**

$$Absorption\ Capacity = \left[\left[\frac{(B - A)}{A} \right] * 100 \right] \dots\dots\dots Equ.6A$$

Table A1- 2: Relative density (Bulk Specific gravity) and Water Absorption Capacity

Crushing site	Test name	Average result of two samples
Wenago crushing site	Relative density on an oven -dry basis	2.45
	Relative density on a SSD basis	2.49
	Apparent relative density (Bulk spe. Gravity)	2.56
	Water Absorption Capacity	1.77
Waleme crushing site	Relative density on an oven -dry basis	2.38
	Relative density on a SSD basis	2.40
	Apparent relative density (Bulk spe. Gravity)	2.41
	Water Absorption Capacity	3.60
Mechisho crushing site	Relative density on an oven -dry basis	2.28
	Relative density on a SSD basis	2.31
	Apparent relative density (Bulk spe. Gravity)	2.37
	Water Absorption Capacity	3.97
Golla crushing site	Relative density on an oven -dry basis	2.47
	Relative density on a SSD basis	2.50
	Apparent relative density (Bulk spe. Gravity)	2.55
	Water Absorption Capacity	1.29

1.3. Moisture content

A = weight of original sample = 3219.3 gm

B = weight of oven dry sample = 3190.7 gm

MC= moisture content (%)

$$MC = \left[\left(\frac{A - B}{B} \right) \right] * 100 \dots\dots\dots Equ.7A$$

Table A1 - 3: Moisture Content of Coarse Aggregate

Sand sample		Weight of Sample before dry (gm) (A)	Weight of Sample after oven dry (gm) (B)	Moisture content (%) (MC)	
Wenago Aggregate	Sample-1	2000	1992.3	0.86	0.88
	Sample-2	2000	1998.4	0.90	
Waleme Aggregate	Sample-1	2000	1993.7	0.97	1.10
	Sample-2	2000	1988.9	1.30	
Mechisho Aggregate	Sample-1	2000	1999.1	0.49	0.52
	Sample-2	2000	1996.8	0.56	
Golla Aggregate	Sample-1	2000	1921.9	1.95	2.10
	Sample-2	2000	1989.1	2.25	

2. Fine Aggregate

2.1. Silt/clay content

A= amount of silt deposited above the sand

B= amount of the sand

S= silt content

$$\text{Silt Content (\%)} = \frac{A}{B} * 100$$

Table.A1- 4: Percentage of Silt/Clay Content of the Sand Sample

Sand Sample		Amount Of Silt Deposited Above The Sand (ml)	Amount Of The Sand (ml)	Silt Content %	Average
Gidabo sand	S1	8	120	5.67	5.23
	S2	6	125	4.80	
Kilkile sand	S1	2	135	1.48	2.49
	S2	5	140	3.5	
Gollelicha sand	S1	5	120	5.16	5.63
	S2	4	130	6.07	

2.2. Sieve Analysis

2.2.1. Gidabo Sand Sample

Table A1- 5: Sieve Analysis for Gidabo Original sand Sample

sieve Size mm(in)	Wt. of sample retained (g)	Wt. retained (%)	Cum. % retained	Cum. % pass	ASTM limits (%)		BS limits (%)	
					Lower	Upper	Lower	Upper
9.5(3/8 in)	0	0	0.00	100	100	100	100	100
4.75(#4)	97.1	8.109	8.109	91.891	95	100	89	100
2.36(#8)	148.5	12.401	20.509	79.491	80	100	60	100
1.18(#16)	233.4	19.491	40.000	60.000	50	85	30	100
0.6(#30)	261.2	21.812	61.812	38.188	25	60	15	100
0.3(#50)	276.2	23.065	84.877	15.123	10	30	5	70
0.15(#100)	141.6	11.825	96.701	3.299	2	10	0	15
0.075(#200)	35.8	2.990	99.691	0.309	0	5		
pan	3.700	0.309	100	0				
Total	1197.5							

➤ Fineness Modulus (FM) for the sand sample

$$\text{Fineness modulus} = \frac{\sum(\text{cum. of } \% \text{ retain})}{100} = \frac{312.0}{100} = 3.12$$

2.3. Particle Size Distribution of Sand Sample

2.3.1. Gidabo sand

Table A1- 6: Particle Size Distribution of Gidabo Sand

Sieve Size mm(in)	Cum. % pass Trail-1	Cum. % pass Trail-2	Ave. Cum. % pass
9.5(3/8 in)	100.000	100	100
4.75(#4)	91.036	89.738	90.387
2.36(#8)	76.861	75.383	76.122
1.18(#16)	55.510	54.603	55.057
0.6(#30)	32.959	32.912	32.936
0.3(#50)	12.297	12.448	12.373
0.15(#100)	2.592	2.781	2.687
0.075(#200)	0.472	0.534	0.503
pan	0	0	0

2.3.2. Calculation on particle size Distribution of fine Aggregate

For instance the particle size distribution for GSU was calculated by using Equ.7A, Equ.8A and Equ.9A. The values in Table 15A was collected from Table 11A and figure 14A that showed the distribution curve of GSU. Equ.8A and Equ.9A was used to determine the coefficient of Uniformity (C_u) and Coefficient of Curvature (C_c) of the fine aggregate samples.

$$C_u = \frac{1.3884}{0.2531} = 5.485 \quad C_c = \frac{(0.5435)^2}{(1.3884 * 0.2531)} = 0.84$$

Table A1- 7: C_u and C_c Values of the Sand Samples

Sand Types		D ₁₀	D ₃₀	D ₆₀	C _u	C _c
Gidabo sand	S1	0.2531	0.5435	1.3884	5.4847	0.8403
	S2	0.2281	0.5284	1.4405	6.3147	0.8497
Kilkile sand	S1	0.3396	0.6723	1.5158	4.4641	0.8782
	S2	0.3135	0.6219	1.4264	4.5505	0.8649
Gollelicha sand	S1	0.2097	0.3439	0.4777	2.2778	1.1804
	S2	0.1617	0.2579	0.4301	2.6600	0.9563

2.4. Unit weight

2.4.1. Compacted and Loose Unit weight

Cylinder (Mold) Mass=4063.2 gm Internal Diameter =15.5cm

Internal Height = 15.5cm Volume of the Mold= 0.002925m³

Table A1- 8: Compacted and Loose Unit weight of all fine aggregate samples

Crushing site	Unit weight test	Average result of two samples (Kg/m ³)
Gidabo Sand	Compacted unit weight	1741.846
	Loose unit weight	1628.582
Kilkile Sand	Compacted unit weight	1599.299
	Loose unit weight	1510.086
Gollelicha Sand	Compacted unit weight	1347.129
	Loose unit weight	1277.009

2.5. Specific gravity (Relative density) and water absorption

Formula used for the calculation of Bulk Specific gravity and water absorption of Fine aggregates.

$$\text{Bulk Spe. gra. (Oven Dry)} = \left[\frac{D}{(A - (B - C))} \right] \dots\dots\dots \text{Equ.12A}$$

$$\text{Spe. gra. (SSD)} = \left[\frac{A}{(A - (B - C))} \right] \dots\dots\dots \text{Equ.13A}$$

$$\text{Apparent Spe. gra.} = \left[\frac{D}{(D - (B - C))} \right] \dots\dots\dots \text{Equ.14A}$$

$$\text{Water Absorption Capacity} = \left[\left[\frac{(A - D)}{D} \right] * 100 \right] \dots\dots\dots \text{Equ.15A}$$

For instance, the bulk specific gravity and water absorption for Gidabo sand was calculated as showed below in the table and also for all the sand samples calculated in this way.

Table A1- 9: Bulk specific gravity (relative density) and water absorption for Gidabo sand

Crushing site	Test name	Average result of two samples
Gidabo sand	Relative density on an oven -dry basis	2.570
	Relative density on a SSD basis	2.594
	Apparent relative density (Bulk spe. Gravity)	2.632
	Water Absorption Capacity	0.914
Kilkile sand	Relative density on an oven -dry basis	2.570
	Relative density on a SSD basis	2.594
	Apparent relative density (Bulk spe. Gravity)	2.632
	Water Absorption Capacity	2.93
Gollelicha sand	Relative density on an oven -dry basis	2.37
	Relative density on a SSD basis	2.53
	Apparent relative density (Bulk spe. Gravity)	2.63
	Water Absorption Capacity	3.34

2.6. Moisture Content

The moisture content of the fine aggregates was performed by using Equ.6A; For instance, the moisture content of the Gidabo Sand for sample-1 and for all sand samples followed the same procedure.

Table A1- 10: Moisture Content for All Sand Samples

Sand sample		Weight of Sample before dry (gm) (A)	Weight of Sample after oven dry (gm) (B)	Moisture content (%) (MC)	
Gidabo sand	Sample-1	914.48	913.6	1.99	2.01
	Sample-2	952.40	951.5	2.03	
Kilkile sand	Sample-1	1594.2	1592.7	1.10	1.40
	Sample-2	2008.7	2006.9	1.80	
Gollelicha sand	Sample-1	1485.2	1464.2	2.46	2.56
	Sample-2	1470.3	1450.3	2.66	

2.7. Bulking of Sand

Bulking of sand samples was determined as showed below

$$BS(\%) = \left[\frac{(A - B)}{B} \right] * 100 \quad \dots\dots\dots\text{Equ.16A}$$

Table A1- 11: Percentage Bulking of Sand for All Sand Samples

Sample of sands		Original volume (V1) ml	Volume after bulking of sand (V2) ml	% of Bulking (BS)	Average Bulking (%)
Gidabo Sand	sample-1	400	360	11.11	10.619
	sample-2	400	363.2	10.13	
Kilkile Sand	sample-1	400	380	5.263	5.041
	sample-2	400	381.6	4.819	
Gollelicha Sand	sample-1	400	360	11.11	9.931
	sample-2	400	367.8	8.75	

2.8. Organic Impurities Test

Table A1 - 12: Organic Impurities Test of the Sand Samples

Item No.	Sand sample	Organic Impurities		Result
		Trail-1	Trail-2	
1	Gidabo sand	5	5	Fail
3	Kilkile sand	3	3	Pass
5	Goleicha sand	5	5	Fail
Key:- 1,2 and 3(standard) satisfactory whereas 4 and 5 unsatisfactory colorimetric test				

3. Hollow concrete block

3.1. Compressive Strength Test results

Table A1 – 13: Compressive Strength Test Result of all sites

HCB production site	HCB size	Average result of compressive strength test of 6 samples (MPa)
Wallelign HCB	20cm	0.89
	15cm	0.90
	10cm	0.94
Hibret HCB	20cm	1.17
	15cm	1.10
	10cm	1.15
Berta HCB	20cm	0.86
	15cm	0.85
Chefe HCB	20cm	1.05
	15cm	1.04

3.2. Absorption of the blocks results

Formula used for the calculation of water absorption capacity of HCB was

$$\text{Water absorption, } \frac{\text{kg}}{\text{m}^3} = \left(\frac{A - B}{A - C} \right) * 100 \dots \dots \dots \text{Equ. 17A}$$

$$\text{Water absorption, \%} = \left(\frac{A - B}{B} \right) * 100 \dots \dots \dots \text{Equ. 18A}$$

Table A1 – 14: Water absorption test result of All HCB sites

HCB production site		Wet mass of blocks, in kg (A)	Dry mass of blocks, in kg (B)	Suspended immersed mass of blocks, in kg (C)	Water absorption, kg/m ³	Water absorption, percent (%)
Walleign HCB	S-1	7.95	6.48	7.02	158.06	22.68
	S-2	8.14	6.62	7.27	174.71	22.96
	S-3	8.05	6.60	7.18	166.67	21.96
	Average				166.48	22.53
Hibret HCB	S-1	8.19	6.95	7.19	124.00	17.84
	S-2	8.38	7.02	7.29	124.77	19.37
	S-3	8.12	6.93	7.27	140.00	17.17
	Average				129.59	18.12
Zemenu HCB	S-1	10.12	8.21	8.92	159.16	23.26
	S-2	9.38	8.06	8.61	171.42	16.37
	S-3	9.54	7.89	8.22	125.00	20.91
	Average				151.86	20.18
Berta HCB	S-1	8.96	7.84	8.22	151.35	14.28
	S-2	8.49	7.77	8.03	156.52	9.26
	S-3	8.87	7.62	8.12	166.67	16.40
	Average				158.18	13.31
Chefe HCB	S-1	9.10	7.66	8.35	192.00	18.79
	S-2	9.08	7.58	8.24	178.57	19.78
	S-3	8.93	7.49	8.09	171.42	19.22
	Average				180.66	19.26

3.3. Block Density

The equation for the calculation of block density used in this research is

$$\text{Density} = \frac{\text{Mass of block in kg}}{\text{Volume of specimen in cm}^3} \times 10^6 \text{ kg/m}^3$$

Table A1 – 15: block density test result of All HCB sites

HCB production site	HCB size	Average result of block density of 3 samples (kg/m ³)
Wallelign HCB	20cm	564.49
	15cm	562.54
	10cm	576.98
Hibret HCB	20cm	653.80
	15cm	655.83
	10cm	668.59
Zemenu HCB	20cm	564.49
	15cm	562.54
Berta HCB	20cm	653.80
	15cm	655.83
Chefe HCB	20cm	653.80
	15cm	655.83

APPENDIX TWO

Concrete Mixing Compressive Strength Results

1. Concrete Mix Design

1.1. Concrete Mix One

This is a concrete mix is produced using wenago coarse aggregate and kilkile fine aggregate.

a. Materials Property

Table A2 – 1: Materials property of concrete mix one ingredients

Mix - One			
Coarse Aggregate		Fine Aggregate	
Walleme Aggregate		Kilkile Sand	
Properties	Result	Properties	Result
Nominal maximum size	25mm	Unit weight	1599.84 Kg/m ³
Unit weight	1641.57 Kg/m ³	Fineness modulus	3.46
Specific gravity	2.49	Specific gravity	2.59
Absorption capacity	1.77%	Absorption capacity	2.93%
Moisture content	0.88%	Moisture content	1.40%

b. Mix Design Calculation

➤ Target Mean Strength

Characteristics strength f_{ck} is 30MPa and take standard deviation of 8N/mm², $k= 1.64$ for 5% defectives.

$$\text{Margin } (C_1) = k*s = 1.64*8 = \underline{\underline{13.12 \text{ N/mm}^2}}$$

$$\text{The target mean strength } (C_2) = f_{ck} + C_1 = 25 + 13 = \underline{\underline{38.12 \text{ N/mm}^2}}$$

➤ Free Water Cement Ratio

Using interpolation between 40MPa and 35MPa value, the W/C ratio for 38.12MPa is 0.449

➤ Mixing Water

As specified, and then approximates mixing water from table 2 for 25mm aggregate size and 50 mm slump and Non air entrained concrete is 180 kg/m³.

$$\text{Water content} = \underline{\underline{180 \text{ kg/m}^3}}$$

➤ **Cement Content**

The cement content can be calculated using

$$\text{Cement content} = \frac{\text{water content}}{\text{W/c}} = \frac{180}{0.449}$$

$$\text{Cement content} = \mathbf{400.89 \text{ kg/m}^3} > \mathbf{300 \text{ kg/m}^3} \dots\dots \mathbf{OK!!!!}$$

➤ **Coarse Aggregate Content**

Volume of dry rodded coarse aggregate per unit volume of concrete for different coarse aggregate and finesse modulus of fine aggregate from table 4 is for 25 mm Max. Aggregate size and 3.46 fineness modulus is calculated by interpolation.

$$\text{Volume of coarse aggregate} = \mathbf{0.625}$$

$$\text{Weight of coarse aggregate} = 0.625 * 1641.57 = \mathbf{1025.98 \text{ kg/m}^3}$$

$$\text{Wet density of concrete} = \mathbf{2355 \text{ kg/m}^3}$$

➤ **Fine aggregate content**

The weight of fine aggregate is calculated by subtracting cement volume, water volume, coarse aggregate volume and air volume from total volume of the concrete.

$$\text{Volume of concrete} = 1 \text{ m}^3$$

$$\text{Volume of water} = 180 / (1 * 1000) = 0.180 \text{ m}^3$$

$$\text{Volume of cement} = 400.89 / (3.15 * 1000) = 0.12 \text{ m}^3$$

$$\text{Volume of coarse aggregate} = 1025.98 / (2.65 * 1000) = 0.387 \text{ m}^3$$

$$\begin{aligned} \text{Volume of fine aggregate} &= \text{concrete vol.} - \text{water vol.} - \text{air vol.} - \text{coarse agg. vol} \\ &= 1 - 0.18 - 0.12 - 0.387 = \mathbf{0.313 \text{ m}^3} \end{aligned}$$

$$\text{Weight of fine aggregate} = 0.313 * 1599.84 = \mathbf{500.74 \text{ kg/m}^3}$$

$$\begin{aligned} \text{Modified wet density of concrete} &= \text{cement} + \text{water} + \text{coarse agg.} + \text{fineagg.} \\ &= 400.89 + 180 + 1026 + 500.74 = \mathbf{2107.63 \text{ kg/m}^3} \end{aligned}$$

c. Proportioning

Table A2 – 2: Proportioning of concrete mix one ingredients

Ingredient	Cement Kg/m³	Water Kg/m³	Fine agg. Kg/m³	Coarse agg. Kg/m³
Quantity(kg/m³)	400.89	180	500.74	1026
For 0.07m³ trial mix	28.06	12.6	35.05	71.82

1.2. Concrete Mix Two

This concrete mix is produced using walleme coarse aggregate and gollelicha sand.

a. Materials property

Table A2 – 3: Materials property of concrete mix two ingredients

Mix - Two			
Coarse Aggregate		Fine Aggregate	
Waleme Aggregate		Gollelicha Sand	
Properties	Result	Properties	Result
Nominal maximum size	25mm	Unit weight	1347.12 Kg/m ³
Unit weight	1270.44 Kg/m ³	Fineness modulus	1.893
Specific gravity	2.40	Specific gravity	2.53
Absorption capacity	3.6%	Absorption capacity	3.34
Moisture content	1.1%	Moisture content	2.58%

b. Mix design calculation

➤ Target mean strength

Characteristics strength f_{ck} is 30MPa and take standard deviation of 8N/mm², $k= 1.64$ for 5% defectives.

The target mean strength (C_2) = 38.12 N/mm²

Free Water Cement Ratio = 0.449

Water content = 180 kg/m³.

Cement content = 400.89 kg/m³ > 300kg/m³..... OK!!!!

➤ Coarse Aggregate Content

Volume of dry rodded coarse aggregate per unit volume of concrete for different coarse aggregate and finesse modulus of fine aggregate from table 4 is for 25 mm Max. Aggregate size and 3.46 fineness modulus is calculated by interpolation.

Volume of coarse aggregate = 0.625

Weight of coarse aggregate = 0.625 * 1270.84 = 794.27kg/m³

Wet density of concrete = 2355 kg/m³

➤ **Fine Aggregate Content**

The weight of fine aggregate is calculated by subtracting cement volume, water volume, coarse aggregate volume and air volume from total volume of the concrete.

$$\text{Volume of water} = 180 / (1 * 1000) = 0.180 \text{m}^3$$

$$\text{Volume of cement} = 400.89 / (3.15 * 1000) = 0.12 \text{m}^3$$

$$\text{Volume of coarse aggregate} = 794.27 / (2.65 * 1000) = 0.299 \text{m}^3$$

$$\begin{aligned} \text{Volume of fine aggregate} &= \text{concrete vol.} - \text{water vol.} - \text{air vol.} - \text{coarse agg. vol} \\ &= 1 - 0.18 - 0.12 - 0.299 = \mathbf{0.401 \text{m}^3} \end{aligned}$$

$$\text{Weight of fine aggregate} = 0.401 * 1347.12 = \mathbf{540.195 \text{kg/m}^3}$$

$$\text{Modified wet density of concrete} = \text{cement} + \text{water} + \text{coarse agg.} + \text{fineagg.}$$

$$= 400.89 + 180 + 794.27 + 540.195 = \mathbf{1915.355 \text{kg/m}^3}$$

c. Proportioning

Table A2 – 4: Proportioning of concrete mix one ingredients

Ingredient	Cement (Kg)	Water (Kg)	Fine agg. (Kg)	Coarse agg. (Kg)
Quantity(kg/m³)	400.89	180	540.2	794.3
For 0.07m³ trial mix	28.06	12.6	37.81	55.60

2. Compressive Strength Test Results

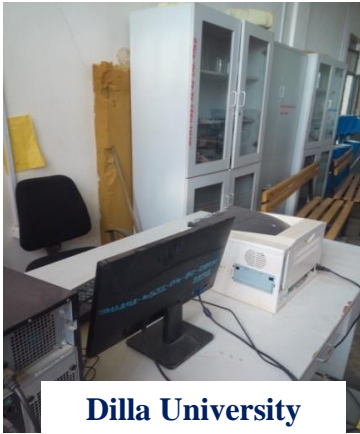
Table A2 – 4: compressive strength test results of concrete

Mix sample	Sample specimen	Weight of sample (Kg)	Maximum load (KN)	Compressive strength (MPa)
7th Days Compressive Strength Results				
Concrete One	Sample - 1	8.41	722.22	32.19
	Sample - 2	8.29	733.91	32.78
	Sample - 3	8.37	700.88	31.28
	Average			32.08
Concrete Two	Sample - 1	8.38	581.44	24.20
	Sample - 2	8.42	597.29	25.31
	Sample - 3	8.29	589.10	24.52
	Average			24.67
28th Days Compressive Strength Results				
Concrete one	Sample - 1	8.28	788.26	35.81
	Sample - 2	8.38	759.39	33.92
	Sample - 3	8.33	772.64	34.84
	Average			34.85
Concrete two	Sample - 1	8.49	637.23	28.31
	Sample - 2	8.41	666.27	29.34
	Sample - 3	8.39	619.26	27.56
	Average			28.40

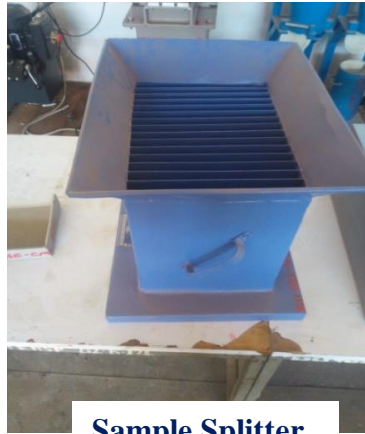
APPENDIX THREE

Sample Photo Gallery Taken During the Research

ii. Equipments Used in Laboratory Investigation



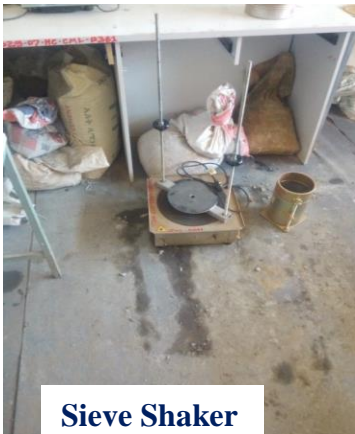
**Dilla University
Laboratory Office**



Sample Splitter



Balance



Sieve Shaker



**Sieves for Fine
Aggregate**



Sample Lay



**Compressive
Strength Machine**



**Sieves for Coarse
Aggregate**



Curing Tank



Specific Gravity test Equipment's



Cylinders for silt content

iii. Laboratory Works



Fine Aggregate Gradation Test



Measuring the Weight of Each Sieves

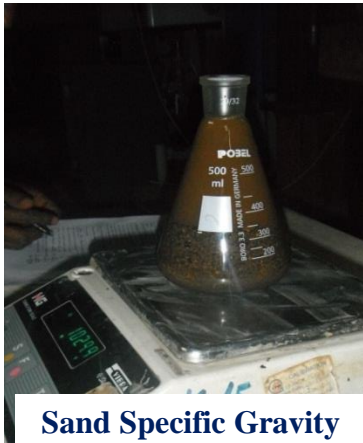


Date Recording



Unit Weight Test for Sand

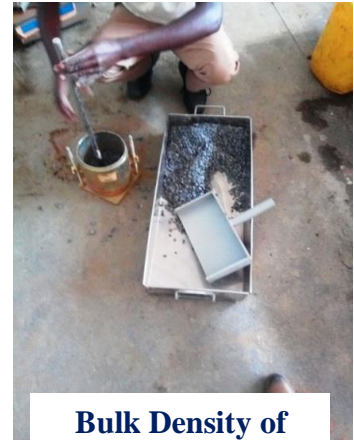




Sand Specific Gravity Test



Organic Impurity Test



Bulk Density of Coarse Aggregate



HCB curing for Absorption Test



HCB Surface Drying



Coping of HCB for Compressive Strength Test



**Setting the
Compression Machine**



**Measuring the
Weight of HCB**



HCB Compression



**Compressive Machine
Output**



Crushed HCB



**Cement used in
Concrete**



Mixing Ingredients



Crushed Concrete

DECLARATION

I hereby declare that, this thesis “**investigation on the production process and quality of Aggregates and Hollow Concrete Blocks: in a case of Gedeo zone**”, is my original work and has not been presented in any other university and all sources of materials used for this thesis have been duly acknowledged.

Name: Tinsae Mengistu Yimer

Signature:

This MSc. Thesis has been submitted for examination with my approval as thesis advisor.

Name: Bahiru Bewket (Dr-Ing)

Signature:

Place and date of submission