Jimma University

School of Graduate Studies

Jimma Institute of Technology

Faculty of Civil and Environmental Engineering

Construction Engineering and Management Chair

Investigation in Suitability of Waste Marble and Ceramic Tiles as a Coarse Aggregate for Production of C-25 Concrete

A thesis submitted to the School of Graduate Studies of Jimma University in Partial fulfillment of the requirements for the Degree of Masters of Science in Civil Engineering (Construction engineering and management)

By

Mintesnot Taderegew(B.Sc)

October, 2017

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Advisor:-Prof.Emer T .Quezon

Co-Advisor :Mr.Mamaru Desalegn(M.Sc)

October, 2017

Jimma, Ethiopia

DECLARATION

“I declare that this research report entitled **“Investigation in Suitability of waste marble and ceramic tiles as a coarse aggregate with and without basalt for C-25 concrete”** is original work of my own, has not been presented for a degree of any other university and that all sources of material used for the thesis have been duly acknowledged.”

Name: Mintesnot Taderegew Kasaye

Signature____________________________ Date________________________

Place: Jimma University Institute of Technology

Faculty of Civil and Environmental Engineering (Construction Engineering and Management Stream)

Date: October, 2017

This is to certify that the above declaration made by the candidate is correct to the best of my knowledge.

Main Advisor: **Prof.Emer T .Quezon**

_______________________ _________________________

Signature date

Co-Advisor: **Mr.Mamaru Desalegn(M.Sc)**

_______________________ _________________________

Signature date

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ABSTRACT

Crushed basaltic stone coarse aggregate serves as one of a conventional concrete aggregate in many world countries including Ethiopia. It has many positive properties that can be said enough for concrete in many constructions. Today our country faced with an important consumption and a growing need for aggregates because of the growth in industrial production and booming constructions, though high amount of construction wastes are available. A high volume of waste material such as waste ceramics and marble tiles from demolished buildings, wastes from completed buildings, supply companies and industries are there, and these waste materials are possibly replace coarse aggregate for concrete mix with their anticipated properties.

The objective of this study was examined the suitability of waste marble and ceramic tiles as a coarse aggregate with and without basalt for C-25 concrete.In order to achieve the objective, ACI mix design method for C-25 concrete at laboratory provision with a water cement ratio of 0.61 was implemented. The sample materials for the laboratory work were collected from JIT, staff condominium renovation and maintenance work, and in the compound of JIT, Jimma University. Six types of concrete mixes, independently three specimens per one curing day, totally 54 samples for each compressive cube and flexural beam besides the material physical properties test.

Based on the results, it showed that the concrete produced with 25% marble tile substitution of basaltic stone coarse aggregate, gave the highest average compressive and flexural strength and followed by 25% ceramic tile substitution of basaltic stone with compressive strength and flexural strength of 35.68Mpa and 5.92 Mpa and 33.11Mpa and 5.52Mpa respectively. While the least compressive and flexural strength was achieved by a concrete mix produced with ceramic tile of 75% and a marble tile of 25 % with average compressive strength of 25.76Mpa and average flexural strength of 4.17Mpa at 28 days of curing period.

Therefore, it conclude that partially 25% waste white marble tile and secondly 25% white paste ceramic tile as a coarse aggregate have significant benefit for the structures in order to enhance the strength with reduced unit weight, good workability and in reductions of wastes from the environment even if they are not much harmful.

.**Keywords***:-Mix design, Compressive strength, Flexural strength, Unit weight, Workability, Suitability*

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ABBREVATIONS

ACI: American Concrete Institute

ASTM: American Society of Testing Material

B=CS: 50% basaltic stone and 50% ceramics tile coarse aggregates

BCS: 75% basaltic stone and 25% ceramics tile coarse aggregates

BMS:75% basaltic stone and 25% marble tile coarse aggregates

BS: British standard

CMS:75% ceramic tile and 25% marble tile coarse aggregates

EBCS: Ethiopian Building Construction Code and Standards

FM: Fineness Modulus

g: Gram

JIT: Jimma Institute of Technology

Kg: Kilogram

Kg/m^3: kilogramper meter cube

MCS:75% marble tile and 25% ceramics tile coarse aggregates

Max: Maximum

Min: Minimum

Mpa: Mega pascal

MR: Modulus of Rupture

MSA: Maximum size of aggregate

NBS: 100% Normal basaltic stone coarse aggregate

OD:Oven dry

SD: Specific Density

SSD: Saturated-surface dry condition

WOD:Weight of oven dry

WSSD: Weight of saturated surface dry

CHAPTER ONE

INTRODUCTION

1.1 Background

Concrete has become inevitable construction material in human life due to wide spread usage in modern construction and its properties like strength and durability. Concrete is a material synonyms with strength and longevity have emerged as the dominant construction material for the infrastructural needs in the present situation. Concrete is highly popular construction material due to its high compressive strength and 10-20% approximate flexural strength at a time [22]. Its virtue is its versatility, i.e. its ability to be molded to take up the shapes required for the various structural forms. It is also workable and fire resistant when specification and construction procedures are correct and it has many positive properties [4].

Concrete is a mixture of cementious material, aggregate, and water. Aggregate is commonly considered inert filler, which accounts for 60 to 80 percent of the volume and 70 to 85 percent of the weight of concrete. Although aggregate is considered inert filler, it is a necessary component that defines the concrete's thermal and elastic properties and dimensional stability. Aggregate is classified as two different types, coarse and fine. Coarse aggregate is usually greater than 4.75 mm (retained on a No. 4 sieve), while fine aggregate is less than 4.75 mm (passing the No. 4 sieve)[9].

Because concrete is an excellent material for resisting compressive loading, it is used in dams, foundations, columns, arches and tunnel linings etc… where the principal loading is in compression[8]. The compressive strength is the most important property of concrete. The characteristic strength that is the concrete grade is measured by the 28 day cube strength. Usually standard cubes of 150*150*150 for aggregates not exceeding or belowsieve parameterare crushed to determine the strength. The compressive strength of concrete depends on the water to cement ratio, degree of compaction, ratio of cement to aggregate, bond between mortar and aggregate, and grading, shape, strength and size of the aggregate. Some of the inner side pages described the compressive strength of concrete from different types of coarse aggregate and their concrete in percentage substitution and proportion which examined in laboratory.

Concrete can be visualized as a multi-phase composite material made up of three phases; namely the mortar, mortar/aggregate interface, and the coarse aggregate phase. When concrete is subjected to compressive loads, failure takes place at one or more of the following locations: (i) within the paste matrix ;(ii) at the paste–aggregate interface; or (iii) within the aggregate. The onset of failure is manifested by crack growth in the concrete. For normal concrete the crack growth is mainly around the cement paste or at the aggregate/cement paste interfacial zone [10]. The strength of concrete at the interfacial zone essentially depends on the integrity of the cement paste and the nature of the coarse aggregate, thus selection of the coarse aggregate is one of the main criteria while formulation of design mix for concrete. This document described the nature of different types of coarse aggregates, standing from their physical properties and their influence that applied on the workability and strength of sample tests.

Flexural strength is one measure of the bending resistance of concrete. It is a measure of unreinforced concrete beam or slab to resist failure in bending. It is measured by loading (100*100) cmconcrete beams with a span length at least five times the depth. The flexural strength is expressed as modulus of rupture (MR) in psi (Mpa) and is determined by standard test methods ASTM C 78(third-point loading or ASTM C 293(center point loading). Many structural components are subject to flexure, or bending. Pavements, slabs and beams are examples of elements that are loaded in flexure. An elementary example is a simple beam loaded at the center and supported at the ends. When this beam is loaded, the bottom fibers (below the neutral axis) are in tension and the upper fibers are in compression [8].This research was executed the examination of six different mixing types of concrete based on three types and different proportions of coarse aggregates and hold the result analysis to see the flexural capacity of concrete.

It is well recognized that coarse aggregate plays an important role in concrete. Coarse aggregate typically occupies over one-third of the volume of concrete, and researches indicates that changes in coarse aggregate can change the compressive strength and Flexural strength of concrete. To predict the behavior of concrete under general loading requires an understanding of the effects of aggregate type, this understanding can only will be gained through extensive testing and observation. Aggregate type is one of the main criteria to determine concrete compressive strength and flexural strength due to aggregates chemical and physical composition with their parameters of properties to be constituent of concrete mix. Coarse aggregates is one of the main constituent of concrete because it not only give the body to the concrete, it also has a significant effect on concrete based on aggregate's shape, size, texture, grading and crushing type[2]. Moreover it is proved that aggregate's types has the severe effect on physic-mechanical properties of concrete as aggregate covered almost 60 to 80 percent of the total volume of concrete.

This paper has been investigated the suitability of different coarse aggregate types namely crushed basaltic stone for both control and partialsubstitution, waste white paste ceramics tile and waste white colored marble tile, on C -25 concrete by orientation of ACI mix design regarding on workability of fresh concrete and compressive and flexural strength of hardenedconcrete .The properties of concrete mixtures were deeply examined in the laboratory before the mix was oriented and different results are recorded accordingly with the importance of using the right type and quality of coarse aggregates in the suitability study. Coarse aggregate occupy over one third of the concrete volume and strongly influence the concrete's freshly mixed and hardened properties, mixture proportions, and economy.

1.2 Statement of the Problem

Constructions from concrete can no longer have high strength and durability unless the coarse aggregate for the structure have positive characteristics that expected from concrete aggregate rock properties. Today's coarse aggregate is coming from multiple tests and experiments regarding on the quality, by the provisions embrace for giving the compressive and flexural strength for the raising structures, in the points of workability and ease of workmanship and the most important adapted by nations and agencies referring by its availability on near surroundings. Different coarse aggregate types find in different environments as conventional concrete main constituent or as a trash in a manner of waste material [13].

Today our country faced with an important consumption and a growing need for aggregates because of the growth in industrial production and booming of constructions, this situation has led to a fast depletion of available resources. On the other hand, a high volume of other waste material such as waste ceramics tile and marble from demolished buildings, wastes from completed buildings while construction proceeds, supply companies and industries, and these wastes considered as they are useless and environmental pollutant, But the materials possibly have the quality to replace concrete coarse aggregate with anticipated properties. Many previous worldwide researchers tried and found few concrete coarse aggregate types that enhance concrete quality regarding on strength, durability freezing and thawing phenomena, workability and so on standing from the lack of occurrences of conventional aggregate, economic and environmental issue and quality.

Concrete mix design essentiality is all about structural better capacity to resist loads. Concrete is expected to have strength to resist compressive and flexural forces. Concrete strength is highly dependent on the mix material quality for paste and aggregate and mix design. Different factors taken into account to select aggregate types by interrelating with structural load capacity: dimensional stability, elastic modulus, density, absorption and surface moisture, soundness, durability, workability, cost of concrete and so on .

The study have been attempted to investigate the suitability of waste marble and ceramic tiles as a coarse aggregate with and without basalt by conducting laboratory works to determine the compressive and flexural strength and to investigate physical properties of waste aggregates.

1.3 Research Questions

1. What are the physical properties of waste ceramic and marble tiles as a coarse aggregate for C-25 concrete?

2. Does waste ceramic and waste marble tile coarse aggregates have a better compressive and flexural strength for C-25 concrete?

3. Which mix ratio can provide the optimum blended coarse aggregate for concrete strengths determination?

1.4 Objectives of the study

1.4.1 General Objective

To investigatethe suitability of waste ceramic and marble tiles as a coarse aggregate with and without crushed basaltic stone for C-25 concrete

1.4.2 Specific Objectives

1.To determine the physical properties of waste marble and ceramic tiles as a coarse aggregate for C-25 concrete

2.To determine the compressive and flexural strength of concrete from blended coarse aggregates of waste marble and ceramic tiles

3. To determine the optimum mix ratio for partially and fully replaced coarse aggregates

1.5 Significance of the Study

There are many inquiry and study that had carried to improvise the quality of concrete production and to create various types of concrete that will be used for different purposes according to its suitability. Many researches had been conducted to intensify the quality or properties of the regular concrete by mixing or adding other materials into the natural conventional concrete. For this study, waste white paste ceramic tile and white colored marble were used to compare with conventional coarse aggregates as a partial substitution and as a whole replacement together. The study is essential because the said materials to replace coarse aggregates are a wastefrom completed construction and collected from the surrounding as a trash and suppliers. And the idea was if waste ceramic tile and waste marble tiles are suitable, they may perhaps be used in concrete production.

This will reduce the waste material from construction as ceramic tile waste and waste marble can be recycled for concrete production purposes. Besides, we can reduce the uses of natural aggregates that are produced from quarrying process which is non-environmental process and harmful to environment. The concrete's production cost can be reduced because the alternative material is waste material that is very low in cost.

1.6 Scope and Limitations of the Study

The scope of the study was limited to investigate the physical properties of different types of coarse aggregates, mix ratio and strength of concrete from waste ceramic and marble tiles with and without crushed basaltic stone coarse aggregate, and to check their outputs in freshly mixed and hardened concrete manner.For this objective by taking a detailed sample of materials for laboratory experiments such as sieve analysis, specific density, absorption and moisture content, unit weight of both fine and different type of coarse aggregates had been executed. For concrete specimens freshly, slump and in hardened state compressive cube test and flexural beam test had been implemented. Thus, from experiment result from laboratory to identify which one of blended coarse aggregates type was better from the others by describing in the parameters of workability, compressive and flexural strength.

CHAPTER TWO

LITERATURE REVIEW

2.1 General

2.1.1 Meaning of Concrete

The word concrete comes from the Latin verb”concretus” which means to grow together. Concrete is basically a mixture of two components: aggregates and paste.The paste, comprised of Portland cement or other types of cement and water, binds the aggregates (usually sand and gravel or crushed stone) into a rocklike mass as the paste hardens because of the chemical reaction of the cement and water [1].

Concrete is one of the versatile and widely used building materials in the world construction industry. Fine and coarse aggregates make about a high percentage volume of concrete production. It goes without saying that the quality of concrete is thus strongly influenced by aggregate’s physical and mechanical properties as well as chemical composition of the parent aggregate making material. Thus in this regards coarse aggregate type plays a great role in giving desirable strength and durability for concrete [2].

2.1.2 Aggregates for Concrete

Aggregates, the major constituent of concrete, influence the properties and performance of both freshly mixed and hardened concrete.When they perform below expectation, unsatisfactory concrete may result. Their important role is frequently over-looked because of their relatively low cost as compared to that of cementitious materials [4].

It is an established fact that the compressive strength of concrete is influenced by, among other things, the quality and proportion of fine and coarse aggregate, the cement paste and the paste-aggregate bond characteristics. These, in turn, depend on the macro and microscopic structural features including total porosity, pore size and shape, pore size distribution and morphology of the hydration products, and the bond between individual solid components. And qualities of concrete such as durability and abrasion resistance are also highly dependent on the aggregate, which in turn depends on strength of parent rock, purity, surface texture, gradation and so on [2].

2.1.3 Aggregate paste interface

The interface between the aggregate and the concrete has been found to be the weakest area in the concrete matrix [11].

A number of factors influence the strength of the aggregate-paste interface and therefore the overall strength of concrete [11];

- Water-to-cement ratio: It has been found that at lower water-to-cement ratios, the strength of the aggregate-paste interface increases.

- Age of concrete: The strength of the aggregate-paste interface has been found to increase with age, provided there is sufficient water.

- Bleeding: Strength decreases with increased bleeding

- Type of cementitious material: Materials containing very fine particles develop stronger aggregate-paste bonds due to the fine filler effect.

- Ultra-fines in aggregates: It has been found that ultrafine material reduces bleeding and causes a fine filler effect at the aggregate-paste interface. Both of these effects will increase the strength of concrete.

- Surface texture of aggregates: Strength has been found to increase with increasing roughness of aggregates.

2.1.4. Compressive strength test of concrete

Test can be made for different purpose but the main two objectives of tests are control of quality and compliance with specification [12].

Compressive strength of concrete: Out of many test applied to the concrete, this is the ultimate important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not (http://theconstructor.org).For cube test two types of specimens either cubes of 15 cm X 15 cm X 15 cm or 10cm X 10 cm x 10 cm depending upon the size of aggregate are used. For most of the works cubical molds of size 15 cm x 15cm x 15 cm are commonly used (http://theconstructor.org).

The concrete is poured in the mold and tempered properly so as not to have any voids. After 24 hours these molds are removed and test specimens are put in water for curing.

The top surface of these specimens should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen. These specimens are tested by compression testing machine after 7 days curing,14 days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete (http://theconstructor.org).

Table:2.1 shows the strength of concrete at different ages in comparison with 28 days age of curing

Age	Strength per cent
1 day	16%
3 days	40%
7 days	65%
14 days	90%
28 days	99%

Table:2.2 Compressive strength of different grades ofconcrete at 7 and 28 days.

Grade of Concrete	Minimum compressive strength N/mm^2 at 7 days	Specified characteristic compressive strength (N/mm^2) at 28 days
M15	10	15
M20	13.5	20
M25	17	25
M30	20	30
M35	23.5	35
M40	27	40
M45	30	45

2.1.5 Flexural strength test of concrete

Flexural testing is used to determine the flex or bending properties of a material. Sometimes referred to as a transverse beam test, it involves placing a sample between two points or supports and initiating a load using a third point or with two points which are respectively call three Point Bend and four Point Bend testing. Maximum stress and strain are calculated on the incremental load applied [13].Flexural MR is about 10 to 20 percent of compressive strength[22].

Calculate the modulus of rupture as follows:

$$R=3PL/2bd^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [Equ.1]$$

where:

R=Modulus of rupture,psi,or MPa

P=maximum applied load indicated by testing machine,lbf,or N

L=span length,in.,or mm

B=average width of specimen,at the fracture,in., or mm, and

D=average depth of specimen,at the fracture,in., or mm

Flexural MR is about 10-20% of compressive strength depending on the type, size and volume of coarse aggregate use. However, the best correlation for specific materials is obtained by laboratory tests for given materials and mix design. The MR determined by center point loading, sometimes by as much as 15% [8].

2.2 Sources of Aggregate and Coarse Aggregate Properties and Standard

2.2.1 Sources of Aggregate

Rocks are classified according to origin into three major groups: namely Natural mineral aggregates, synthetic (artificial)aggregates and recycled aggregates

2.2.1.1 Natural Mineral Aggregates

Almost all natural aggregate materials originate from bed rocks. There are three kinds of rocks, namely, igneous, sedimentary and metamorphic. These classifications are based on the mode of formation of rocks: Sand, gravel, and crushed rock derived from natural sources [14]

(I) **Igneous Rocks** -formed on cooling of the magma (molten rock matter) or lava at the surface of the crest (trap and basalt) or deep beneath the crest (granite)[14].Basalt, : hard, tough, strong:-Excellent aggregates [3]. Basalts are dark colored, fine grained extrusive rocks. The mineral grains are so fine that they are impossible to distinguish with the naked eye or even a magnifying glass. Most basalt is volcanic in origin and was formed by the rapid cooling and hardening of the lava flows. Some basalt is intrusive having cooled inside the Earth’s interior [15].

(II) **Sedimentary Rocks** -The sedimentary rocks are formed originally below the sea bed and subsequently up. Metamorphic rocks are originally either igneous or sedimentary rocks which are subsequently metamorphosed due to extreme heat and pressure [14], Stratified rocks (cost effective–near the surface; Limestone, Sandstone: Excellent to poorin there toughness and suitability as a coarse aggregate [3].

(III) **Metamorphic Rocks** -Igneous or sedimentary rocks that have changed their original texture, crystal structure, or mineralogy composition due to physical and chemical conditions below the earth's surface. [3].

Marble, schist, slate:-Excellent to poor

A variety of properties can be described to characterize aggregate. Many of these properties can be measured using standard tests. Chemical properties of aggregate are important in the manufacture of concrete. Excessive amount of contaminants may cause decrease strength and durability of aggregate, may affect the quality of bond between the cement and aggregate, may bond unsightly appurtenance may inhibit the hydration of cement .weathering of bedrock or gravel clasps lesson the strength of aggregate, increase the overall costs of separating the good from bad rock, and influences the blasting and extracting techniques employed. Maps of potential sources of aggregate should include description of these properties as well as delineate the areal extent and thickness of the potential aggregate source [6].

2.2.1.2 Synthetic Aggregates

Aggregate types such as thermally processed materials i.e. expanded clays and shale and

Aggregates made from industrial by-products, i.e. blast-furnace slag & fly ash [3].

2.2.1.3 Recycled Aggregates

- Made from municipal wastes, terminated components and recycled concrete from demolished buildings and pavements and other structures. Examples. Waste ceramics aggregates [3].
- Problems: Cost of crushing, grading, dust control, and separation of undesirable constituents.

2.2.2. Coarse Aggregate Properties and Standard

2.2.2.1Aggregate Characteristics Affecting Concrete Behavior

Characteristics controlled in terms of porosity will be as follows:

2.2.2.1.1 Density

I) **ApparentSpecific Gravity**: Density of the material including the internal pores.

II) **Specific Gravity**: The density of the aggregate is required in mix proportioning to establish weightvolume relationships. The density is expressed as the specific gravity, which is a dimensionless ratio relating the density of the aggregate to that of water [1]. The specific gravity (relative density) of an aggregate is the ratio of its weight to the weight of an equal volume of water [3].

Most natural aggregates have specific gravities between 2.4 and 3.0

$$SG = \frac{\text{Density Of Solid}}{\text{Density Of Water}} \text{……………………………………………}[\text{Equ.2}]$$

Because the aggregate mass varies with its moisture content, specific gravity is determined at fixed moisture content.

II) **Bulk Density** (dry-rodded unit weight) weight of aggregate that would fill a unit volume;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 [2b].Bulk Density affects the following concrete behavior: mix design, workability, and unit weight [3].and the bulk density is affected by mainly by moisture contents of aggregate and grading, specific gravity, surface texture, shape, and angularity of particles respectively.The rodded bulk density of aggregates used for normal weight concrete generally ranges from 1200 to 1760 kg/m3 [16].

2.2.2.1.2 Absorption and Surface Moisture

Absorption:-The increase in the weight of aggregate due to water in the pores of the material, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry weight. The aggregate is considered “dry” when it has been maintained at a temperature of 110 ±5°C for sufficient time to remove all uncombined water [23].

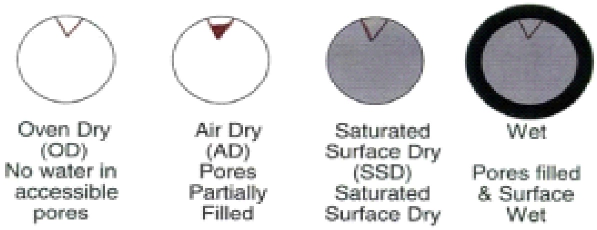


Figure 2.1: Moisture conditions of aggregate

Moisture conditions of aggregates:-

- **Oven-dry Condition**: All free moisture, whether external surface moisture or internal moisture, driven off by heat.
- **Air dry:** No surface moisture, but some internal moisture remains
- **Saturated-surface dry condition** (SSD): Aggregates are not said to be SSD when their moisture states are during mixing they willabsorb any of the mixing water added; nor will they contribute any of their contained water to the mix. Note that aggregates in SSD condition may possess “bound water” (water held by physical-chemical bonds at the surface) on their surfaces since this water cannot be easily removed from the aggregate[3].
- **Damp or Wet condition**: Aggregate containing moisture in excess of the SSD condition.
- **The Free Water**, which will become part of the mixing water, is in excess of the SSD condition of the aggregate.

Absorption and surface moisture affects the following concrete behaviors: mix-design, strength / abrasion resistance

Free Moisture and Absorption of Aggregates

- The moisture content and absorption of aggregates are important in calculating the proportions of concrete mixes since any excess water in the aggregates will be incorporated in the cement paste and give it a higher water/cement ratio than expected [3].
- All moisture conditions are expressed in terms of oven dry unit weight.

Absorption is computed as a percentage by subtracting the oven-dry mass from the saturated surface-dry mass, dividing by the oven-dry mass, and multiplying by 100. In concrete technology, aggregate moisture is expressed as a percent of the dry weight of the aggregate [16].

Absorption, %, $=((W_{SSD}-W_{OD})/W_{OD})\times 100$ ………………. [Equ.3]

2.2.2.1.3 Soundness

Aggregate is considered unsound when volume changes in the aggregate induced by weather, such as alternate cycles of wetting and drying or freezing and thawing, result in concrete deterioration [3].Soundness of an aggregate refers to its ability in concrete to withstand aggressive exposure, particularly due to weather. In areas with severe or moderate winters, a major cause ofaggregate deterioration in exposed concrete is freezing and thawing. If an aggregate particle absorbs so much water that its pores are nearly completely filled, it may not accommodate the expansion that occurs when water turns to ice. As ice forms, the resulting expansion pushes unfrozen water through the aggregate pores and the resistance to this flow results in pressures that may be high enough to crack the particle. These pressures may crack the aggregate particle, and, in concrete, the surrounding concrete as well. This is known as "D-cracking." The developed pressure depends on the rate of freezing and the particle size above which the particle will fail if completely saturated. This critical size depends on the porosity, pore size, and total pore volume of the aggregate; the permeability or rate of discharge of water flowing through the aggregate; and the tensile strength of the particle. For fine-grained aggregates with low permeability (such as some cherts), the critical particle size may be in the range of normal aggregate sizes. It is higher for coarse-grained materials or those with pore systems interrupted by numerous pores too large to hold water by capillary action. For these materials, the critical size may be too large to be of consequence, even though absorption may be high. Also, if potentially vulnerable aggregates are dry when used or are used in concrete subjected to periodic drying while in service, they may never become sufficiently saturated to cause failure under freezing and-thawing cycling16].

Some specifications may require that resistance to weathering be demonstrated by the sodium sulfate or magnesium sulfate soundness test (ASTM C 88). This test consists of immersing a sample of the aggregate specimen in a sulfate solution for a prescribed number of cycles, oven-drying the sample, and determining the percentage loss of mass.

This test sometimes produces inconsistent results, in that aggregates behaving satisfactorily in the test may produce concrete having low freezing-and-thawing resistance; conversely, aggregates performing poorly may produce concrete with adequate resistance. This may be attributed in part to the fact that the aggregates in the test are not surrounded by cement paste as they would be when used in concrete [16].

- Depends on: porosity, flaws and contaminants.
- Pumice: (10% absorption) - no problem with freezing and thawing.
- Limestone breaks: use smaller aggregates (critical size)

(Critical aggregate size: size below which high internal stresses capable of cracking the particle will not occur)

2.2.2.2 Characteristics Dependent on Prior Exposure and Processing Factors

2.2.2.2.1 Aggregate size

In specifications for aggregates, the smallest sieve opening through which the entire amount of aggregate is required to pass is called the maximum size. The smallest sieve opening through which the entire amount of aggregate is permitted to pass is called the nominal maximum 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. ASTM grading requirements are based on nominal maximum size [1].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:

a) Reduction of cement content

b) Reduction in water requirement

c) Reduction of drying shrinkage [17].

The maximum size of aggregate that can be used generally depends on the size and shape of the concrete member and the amount and distribution of reinforcing steel. The maximum size of aggregate particles generally should not exceed: One-third the depth of slabs

- MSA < 1/5 of the narrowest dimension of the form in which concrete is to be placed.
- Also: MSA < 3/4 of the maximum clear distance between the re-bars One-third the depth of slabs
- Aggregate size affects the following concrete properties: water demand, cement content, micro cracking (strength)[3].

2.2.2.2.2 Aggregate Grading

The distribution of particles of granular materials among various sizes or grading is determined in accordance with ASTM C 136, "Sieve or Screen Analysis of Fine and Coarse Aggregates." A sample of the aggregate is shaken through a series of wire-cloth sieves with square openings, nested one above the other in order of size, with the sieve having the largest openings on top, the one having the smallest openings at the bottom, and a pan underneath to catch material passing the finest sieve [16].That 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" [16].Gradation plays an important role in the workability, segregation, and pump ability of the concrete. Grading changes are more prevalent than shape and surface texture in the case of coarse aggregates

Significance of aggregate grading:-There are several reasons for specifying both grading limits and maximum aggregate size. Aggregates having a smooth grading curve and neither a deficiency nor excess of any one particle size generally produce mixtures with fewer voids between particles. Because cement costs more than aggregate and the cement paste requirement for concrete increases with increasing void content of the combined aggregates, it is desirable to keep the void content as low as possible. If there is not enough fine aggregate to fill the voids between coarse aggregate particles, the space must be filled with cement paste. Such under-sanded mixtures also tend to be harsh and difficult to finish. On the other hand, aggregate combinations with excessive amounts of fine aggregate or excessively fine sands may produce uneconomical concretes because of the larger surface area of finer particles, which requires additional cement.

A. 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.

The maximum size of coarse aggregate used in concrete also affects surface area and economy. Usually, as the maximum size of well-graded coarse aggregate increases, the amount of paste required to produce concrete of a given slump or consistency decreases. If some of material is replaced with 19.0 and 25.0 mm (3/4 and 1 in.) particles, the surface area and the void content decrease, because a number of smaller particles and the voids between them are replaced by a single larger particle. If too many larger particles were added, however, there would not be enough fines to fill the voids between them and voids would increase again due to the poor grading. The maximum nominal size of aggregate that can be used is determined by the size and shape of the concrete member and by the clear spacing between reinforcing bars. In general, nominal maximum size should not be more than one-fifth of the narrowest dimension between sides of forms, one-third the depth of slabs, or three-fourths of the minimum clear spacing between reinforcing bars. Use of the largest possible maximum aggregate size consistent with placing requirements is sometimes recommended to minimize the amount of cement required and to minimize drying shrinkage of concrete. Aggregates of different maximum sizes, however, may give different concrete strengths for the same water-cementitious material ratio (w/cm). In many instances, at the same w/cm, concrete with smaller maximum-size aggregate has higher compressive strength. This is especially true in strength ranges in excess of 35 MPa (5100 psi). An aggregate having a maximum size of 19.0 mm (3/4 in.) or smaller may be the most efficient in that its use will require the least amount of cement to produce the required strength. One of the most important characteristics of the fine aggregate grading is the amount of material passing the 300 and 150 µm (No. 50 and 100) sieves. Inadequate amounts of materials in these size ranges can cause excessive bleeding, difficulties in pumping concrete, and difficulties in obtaining smooth troweled surfaces. Most specifications allow 10 to 30% to pass the 300 µm (No. 50) sieve, and 2 to 10% to pass the 150 µm (No. 100) sieve. ASTM C 33 permits the lower limits for percent passing the 300 and 150 µm (No. 50 and 100) sieves to be reduced to 5 and 0, respectively. A precautionary note in ASTM C 33 states that to alleviate potential problems with decreased fines, one can add entrained air, additional cement, or a supplemental cementitious material to supply the deficient fines [16].

- Depends on: proportions of coarse and fine aggregates
- Affects: Paste content (cost economy), workability.

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 anticipate, 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. The actual grading requirements for coarse aggregate depend to some extent on the shape and surface characteristics of the particles. For instance, sharp, angular particles with rough surfaces should have a slightly finer grading in order to reduce the possibility of interlocking and to compensate for the high friction between the particles [16].

B. Fine-Aggregate Grading

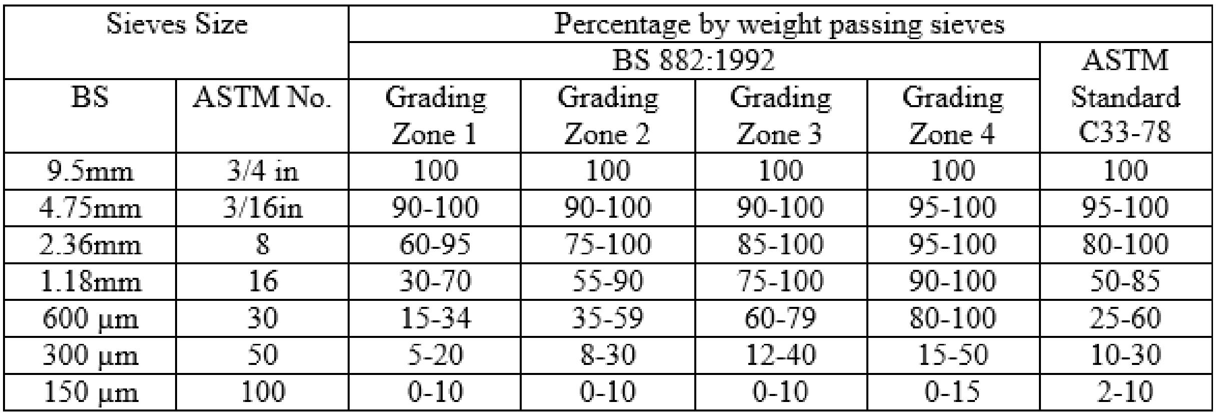
The most desirable fine-aggregate grading depends on the type of work, the fruitfulness of the mixture, and the maximum size of coarse aggregate. In leaner mixtures, or when small-size coarse aggregates are used, a grading that approaches the maximum recommended percentage passing each sieve is desirable for workability. In general, if the water-cement ratio is kept constant and the ratio of fine-to-coarse aggregate is chosen correctly, a wide range in grading can be used without measurable effect on strength. However, the best economy will sometimes be achieved by adjusting the concrete mixture to suit the gradation of the local aggregates (Kosmatka, et al., 2003).

Fine aggregate grading has a greater effect on workability of concrete than coarse aggregates. Manufactured sands require more fines than natural sands to achieve the same level of workability, probably due to the angularity of the manufactured sands particles [17]

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 [12].

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.

Table2.3:BS and ASTM grading requirement for fine aggregate (Neville, 1999).



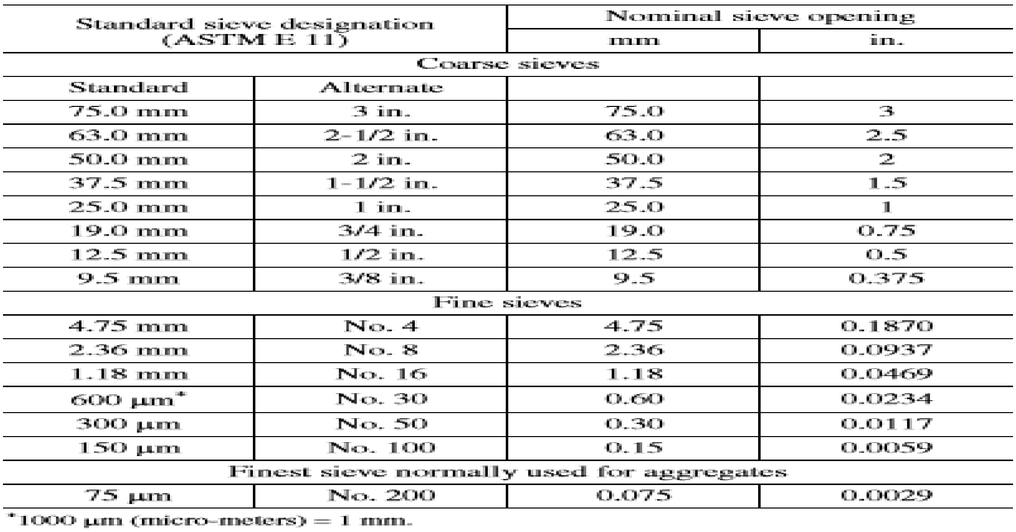
Sieves Size		Percentage by weight passing sieves				
		BS 882:1992				ASTM Standard C33-78
BS	ASTM No.	Grading Zone 1	Grading Zone 2	Grading Zone 3	Grading Zone 4	
9.5mm	3/4 in	100	100	100	100	100
4.75mm	3/16in	90-100	90-100	90-100	95-100	95-100
2.36mm	8	60-95	75-100	85-100	95-100	80-100
1.18mm	16	30-70	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

Sand falling in to any of the above zone can generally be used in concrete although under some circumstances the suitability of the given sand may depend on the grading and shape of coarse aggregate. Subjected value of Coarse to fine aggregate ratio is given in Table 2.3 as follows (Neville, 1999).

Table2.4:Suggested proportion by weight of Coarse to fine aggregate for sand of different zones

Maximum Size Of Coarse Aggregate		Coarse/fine aggregate ratio for sand of different zone			
		Zone 1	Zone 2	Zone 3	Zone 4
mm	in				
9.52	3/8	1	1.5	2	3
19.05	3/4	1.5	2	3	3.5
38.1	1 1/2	2	3	3.5	-

Table 2.5 :ASTM standard sieve designation for both fine and coarse aggregates

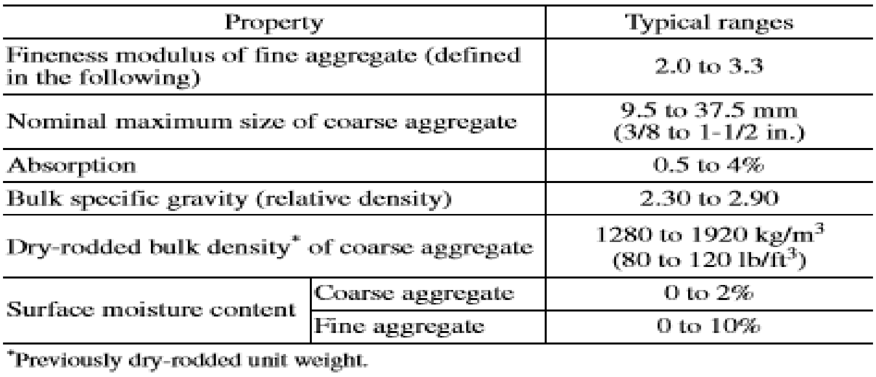


Standard sieve designation (ASTM E 11)		Nominal sieve opening	
		mm	in.
Coarse sieves			
Standard	Alternate		
75.0 mm	3 in.	75.0	3
63.0 mm	2-1/2 in.	63.0	2.5
50.0 mm	2 in.	50.0	2
37.5 mm	1-1/2 in.	37.5	1.5
25.0 mm	1 in.	25.0	1
19.0 mm	3/4 in.	19.0	0.75
12.5 mm	1/2 in.	12.5	0.5
9.5 mm	3/8 in.	9.5	0.375
Fine sieves			
4.75 mm	No. 4	4.75	0.1870
2.36 mm	No. 8	2.36	0.0937
1.18 mm	No. 16	1.18	0.0469
600 µm*	No. 30	0.60	0.0234
300 µm	No. 50	0.30	0.0117
150 µm	No. 100	0.15	0.0059
Finest sieve normally used for aggregates			
75 µm	No. 200	0.075	0.0029

*1000 µm (micro-meters) = 1 mm.

The below table shown the physical property of aggregates that helps for designing the mix design

Table 2.6: Common physical property range of concrete aggregates for mix design [16]



Property		Typical ranges
Fineness modulus of fine aggregate (defined in the following)		2.0 to 3.3
Nominal maximum size of coarse aggregate		9.5 to 37.5 mm (3/8 to 1-1/2 in.)
Absorption		0.5 to 4%
Bulk specific gravity (relative density)		2.30 to 2.90
Dry-rodded bulk density* of coarse aggregate		1280 to 1920 kg/m^3 (80 to 120 lb/ft^3)
Surface moisture content	Coarse aggregate	0 to 2%
	Fine aggregate	0 to 10%

*Previously dry-rodded unit weight.

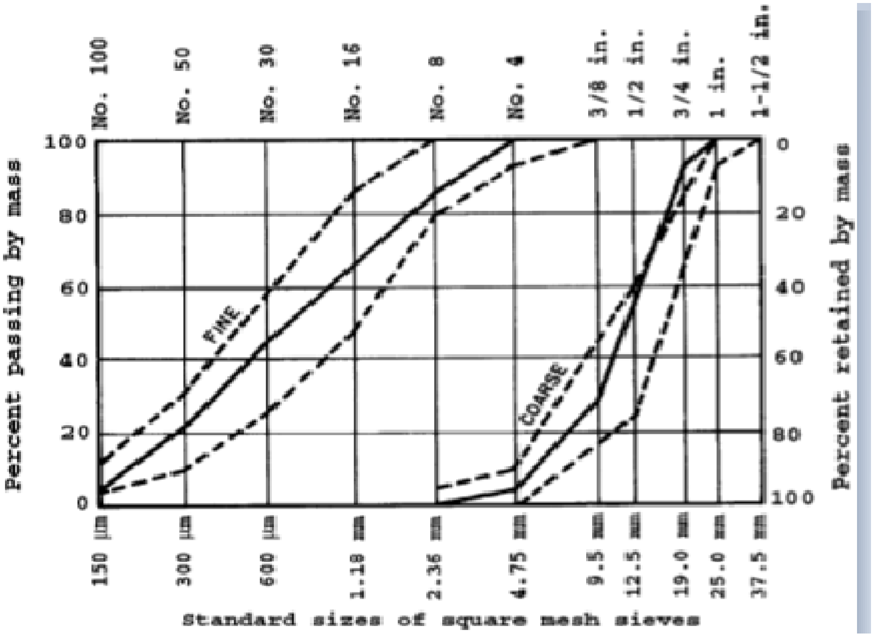


Figure 2.2: Typical grading chart, specified in ASTM C 33 for fine and 25mm nominal coarse aggregate size

NB: Dashed lines shows the limit

2.2.2.2.3 Fineness Modulus (FM)

Fineness Modulus (FM) is index of fineness of an aggregate.

It is computed by adding the cumulative percentages of aggregate retained on each of the Specified series of sieves, and dividing the sum by 100 [smallest size sieve: No. 100 (150 µm)].

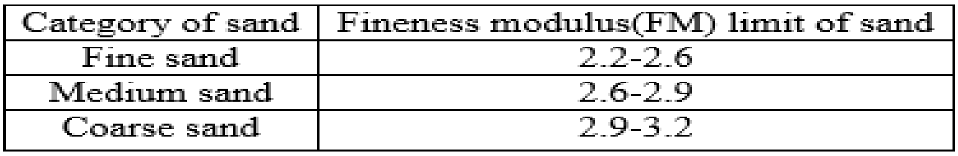
$$\text{Fineness modulus} = \frac{\sum (cum.of\ \%retain)}{100}$$ .... [Equ.4]

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. 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, 600 µm, 300 µm, and 150 µm (No. 4, 8, 16, 30, 50, and 100). Note that the lower limit of the specified series of sieves is the 150 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 the aggregate, the higher the FM. For fine aggregate used in concrete, the FM generally ranges from 2.3 to 3.1 as called for in ASTM C 33, but in some cases, fine sands are used with an FM less than 2.0 [16]

Note that all of the FM sieves below the maximum size (that has nothing retained, 3 /8 in. in this case) must be included and none of the non-FM sieves can be included. For example, if a No. 200 or a 1/2 in. sieve were included in the sieve analysis, the cumulative percent retained on those sieves would not be included in the FM calculation because they are not in the FM series. Although the FM is most commonly computed for fine aggregates, the FM of coarse aggregate is needed for some proportioning methods. It is calculated in the same manner, while taking care to exclude sieves that are not specified in the definition (for example, 25.0 and 12.5 mm [l and 1/2 in.] sieves) and to include all of the specified finer sieves [16]

- Note: The higher the FM, the coarser the aggregate.
- The fineness modulus can be considered as a weighted average size of a sieve on which the material is retained, keeping in mind that the sieves are counted from the finest [3].
- For instance, a fineness modulus of 4.00 can be interpreted to mean the fourth sieve, No. 16 in the US series, is the average size [3].
- It is important to note that the fineness modulus is just one number which only characterizes the average size of the aggregate, and different grading's may have the same fineness modules [3].

Table 2.7: 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

C. Shape and Surface Texture

The shape of the aggregate particles influences paste demand, placement characteristics such as workability and pump ability, strength and cost. Shape is related to sphericity, form, angularity, and roundness [24].

Rough-textured and elongated particles require more cement paste to produce workable concrete mixtures, thus increasing the cost.

- The sphericity measures how nearly equal are the three principal axis of the aggregate (length L, width W, and height H). The sphericity increases as the three dimensions approach equal values.The form or the shape factor, describes the relative proportions of the three axes of a particle. It helps distinguish between particles that have the same sphericity
- The angularity describes the proportions of the average radius of curvature of corners and edges to the radius of maximum inscribed circle.
- The roundness describes the sharpness of the edges and corners Particle shape can be classified by the following descriptions:

- Sphericity and form: cubical, spherical, flat or elongated
- Angularity & roundness: Angular, sub angular, sub rounded, rounded, and well rounded
- Round- loosing edges and corners.
- Angular- well defined edges and corners.
- Elongated- when length is considerably larger than the other two dimensions.
- Flaky or flat- when thickness is small relative to two other dimensions.

Surface Texture- the degree to which the aggregate surface is smooth or rough-(based on visual judgment): depends on: rock hardness, grain size, porosity, previous exposure, Affects: Workability, paste demand, initial strength [3].

- Most natural aggregates have specific gravities between 2.4 and 3.0

2.3 Quality Requirements for Aggregates

In choosing aggregate for use in a particular concrete, attention should be given among other things to three important requirements [18].

1) Workability, when fresh for which the size and gradation of the aggregate should be such that undue labor in mixing and placing will not be required.

2) Strength and durability when hardened for which the aggregate should be: a) Be stronger than the required concrete strength b) Contain no impurities which adversely affect strength and durability c) Not go in to undesirable reaction with the cement d) Be resistant to weathering action .

3) Economy of the mixture –meaning to say that the aggregate should be : a) Available from local and easily accessible deposit or quarry b) Well graded in order to minimize paste hence cement requirement

- The strength requirement for aggregate can be organized in quality of ingredients and method and situation of mixing
- The durability requirements for aggregate can be organized into deleterious substances and reactive aggregates. The deleterious substances are listed below:
- Substances causing a chemical reaction.
- Substances which undergo disruptive expansion.
- Clay and other surface coatings.
- Aggregate particles with flat or elongated shape.
- Structurally soft and/or weak particles.
- The rougher the surface of the aggregate and the greater the area in contact with the cement paste, the stronger a concrete will be.
- Rounded particles result in lower strength than crushed aggregates.
- Larger size aggregates lead to lower strength in concrete

2.4 Engineering Properties of Natural Aggregate

The table below holds necessary natural aggregate engineering properties which support them to be concrete constituents

Table 2.8: Engineering Properties of Natural Aggregate

physical soundness The ability of an aggregate to resist weathering, particularly freezing and thawing and wetting-drying cycles	:generally aggregate that contain weak, cleavable, absorptive, or swelling particles are not suitably sound, examples are shales, sandstones .lime stones clayey rocks, some very coarse crystalline rocks and porous cherts

	(gillot,1980:Neville 1973).weathered rock types such as weathered igneous rocks where secondly clay minerals are produced, can also be unsound(fookes 1980).however because the physical properties of the rocks, not their composition, controls frost susceptibility, not all these types of rocks have durability problems. The most important physical property of rock articles affecting weathering resistance (particularly freezing and thawing) is the size abundance, continuity of pores. channels and fractures(McLaughlin and others,1960)these provide conduits for the passage of water ,which in turn accelerate the weathering process.it is generally accepted that there is an approximate correlation between quality(soundness) and rock porosity. a rough working rule is that rock with a water absorption value of less than 2 percent will usually produce quality aggregate, whereas those with values greater than 4 percent generally will not(smith and collia,1003).specifications for soundness are similar for aggregates to be used in concrete
Hardness, strength, and toughness, hardness(resistance to load),strength(resistance to abrasion),and toughness(resistance to impact)of aggregates determine their ability to resist mechanical breakdown)	Hardness, strength and toughness are generally controlled by the individual mineral constituents of rock particles, the strength with which these minerals are locked or cemented together, and the abundance of fractures. Particles consisting of minerals with a low degree of hardness are considered to be sort. those which are easily broken down, due to weak bonding or cementation or to fracturing are considered to be weak (McLaughlin and others,1960)soft or weak

	particles are deleterious in aggregate because they perform poorly in use and because they break down during handling, thus affecting the grading of the aggregate Mechanical breakdown of the aggregate due to the action of mixer, mechanical equipment and (or) traffic, or breakdown due to weathering is referred to as aggregate degradation. Degradation can occur due to compressive failure of grains at points of contact.as well as to abrasive action of grains on each other [3].

2.5 Coarse Aggregate Production in Ethiopia

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. 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.[2].

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 [2].

2.5 Experiences in Using Different Types of Coarse Aggregates

2.5.1 Crushed basaltic Coarse Aggregate

Basaltic coarse aggregate is categorized under igneous rock type which is a usual aggregate type in many of world countries and it is available in every continent.Basalts are dark colored, fine grained extrusive rocks; hard, tough excellent aggregate, naturally occurring concrete aggregates are a mixture of rocks and minerals. A mineral is a naturally occurring solid substance with an orderly internal structure and a chemical composition that ranges within its own limits. Rocks, which are classified as igneous, sedimentary, or metamorphic, depending on origin, are generally composed of several minerals. For example, basalt contains quartz, feldspar, mica, and a few other minerals. The basalt mix had the best elastic compatibility between the matrix and aggregate. In our country this type of aggregate occur predominantly and it serves as a coarse and manufactured fine aggregate for almost all construction projects.

2.5.2 Waste Ceramic Tile as a Coarse Aggregate

Ceramic products are part of the essential construction materials used in most buildings. Some common manufactured ceramics include wall tiles, floor tiles, sanitary ware, household ceramics and technical ceramics. They are mostly produced using natural materials that contain high content of clay minerals. However, despite the ornamental benefits of ceramics, its wastes among others cause a lot of nuisance to the environment. Numerous researchers have identified ceramics as having the potential to replace natural aggregates and some investigations have suggested that ceramic wastes are good materials which could substitute conventional aggregates in concrete. The influence of ceramic tiles wastes on the structural properties of concrete made using laterite was recently investigated. It was reported that ceramic based laterized concrete performed considerably well when compared to the conventional concrete. Overall, ceramic waste utilization can solve problems of aggregate shortages in various construction sites. Moreover it can reduce environmental problems related to aggregate mining and waste disposal.in Ethiopia construction industry there is no usage of ceramic waste as an aggregate by replacing crushed stone but many worldwide researches are prepared by researchers in regards of how to use ceramics wastes as a coarse aggregate by different partial replacement percent and as a whole by replacing conventional aggregate [7].

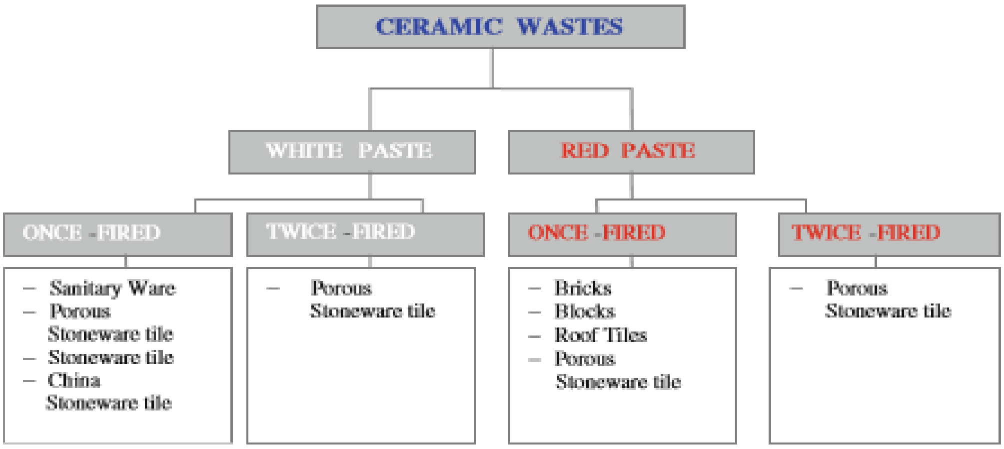
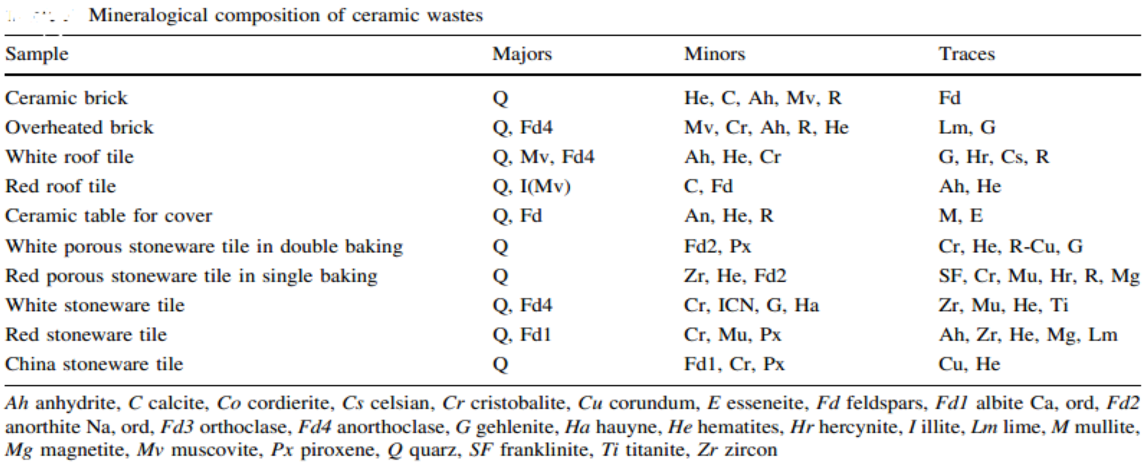


Figure 2.3: ceramic waste aggregate types from the kinds of productions

Ceramic wastes are produced as a result of the ceramic processing. These wastes cause soil, air, and groundwater pollution. Ceramic wastes can be separated in two categories in accordance with the source of raw materials. The first one are all fired wastes generated by the structural ceramic factories that use only red pastes to manufacture their products, such as brick, blocks, and roof tiles. The second one is all fired waste produced in stoneware ceramic such as wall, floor tiles and sanitary ware [7].

Table 2.9: Mineralogical composition of ceramic materials



Mineralogical composition of ceramic wastes

Sample	Majors	Minors	Traces
Ceramic brick	Q	He, C, Ah, Mv, R	Fd
Overheated brick	Q, Fd4	Mv, Cr, Ah, R, He	Lm, G
White roof tile	Q, Mv, Fd4	Ah, He, Cr	G, Hr, Cs, R
Red roof tile	Q, I(Mv)	C, Fd	Ah, He
Ceramic table for cover	Q, Fd	An, He, R	M, E
White porous stoneware tile in double baking	Q	Fd2, Px	Cr, He, R-Cu, G
Red porous stoneware tile in single baking	Q	Zr, He, Fd2	SF, Cr, Mu, Hr, R, Mg
White stoneware tile	Q, Fd4	Cr, ICN, G, Ha	Zr, Mu, He, Ti
Red stoneware tile	Q, Fd1	Cr, Mu, Px	Ah, Zr, He, Mg, Lm
China stoneware tile	Q	Fd1, Cr, Px	Cu, He

Ah anhydrite, *C* calcite, *Co* cordierite, *Cs* celsian, *Cr* cristobalite, *Cu* corundum, *E* esseneite, *Fd* feldspars, *Fd1* albite Ca, ord, *Fd2* anorthite Na, ord, *Fd3* orthoclase, *Fd4* anorthoclase, *G* gehlenite, *Ha* hauyne, *He* hematites, *Hr* hercynite, *I* illite, *Lm* lime, *M* mullite, *Mg* magnetite, *Mv* muscovite, *Px* piroxene, *Q* quarz, *SF* franklinite, *Ti* titanite, *Zr* zircon

RM. Senthamarai and P. DevadasManoharan stated that, the surface texture of the ceramic waste aggregate was found to be smoother than that of crushed stone aggregate. In the soundness test, after 30 cycles, the weight loss of ceramic waste aggregate was 51% less than that of conventional crushed stone aggregate, since ceramics have more resistance against all chemicals. In general, ceramic waste aggregate showedproperties close to those of natural crushed stone aggregate [20].

RM. Senthamarai and P. DevadasManoharan also stated thatCeramic waste can be transformed into useful coarse aggregate. The properties of ceramic waste coarse aggregate are well within the range of the values of concretemaking aggregates. The compressive, splitting tensile and flexural strengths of ceramic waste coarse aggregate concrete are lower by 3.8, 18.2 and 6% respectively when compared to conventional concrete, but ceramic waste coarse aggregate concrete possesses lower tensile to compressive strength ratio. The properties of ceramic waste coarse aggregate concrete are not significantly different from those of conventional concrete[20].

The shape and texture of ceramic tile coarse aggregate is flaky and rough in all sides except the top respectively.

Dr. Rakesh Kumar Singla and Parminder Singhstated that Ceramic tile aggregate is an appreciated and appropriate concrete material for substitution into concrete composition based on its properties.Mechanical properties of ceramic aggregate are similar to the natural aggregate and its behavior is similar but not same. Water absorption, crushing value and impact value, are higher than natural coarse aggregate and lower by specific gravity i.e. 2.24 g/cm3.It is possible in M 20 grade concrete to substitute 20% of normal 20 mm aggregates with ceramic tile aggregates without compromising its required compressive strength but for all concrete mixes (M 20, M25, M30) compression strength of concrete decreases with increase in the proportion of replacement of natural aggregates with tile aggregates which is due to low specific gravity higher porosity of tile aggregates as compare to natural aggregates [21].

2.5.3 Waste Marble Tile as a Coarse Aggregate

The most interesting deposits of marble are found in the western part of Wellega (Daleti) and Gojam (Mora, Bulen,Mankush and Baruda). The area is quite remote, and transport distances toAddis Ababa vary between 550 and 800 km,for the most part along non-paved roads. However, at the present time,transport costs are still low enough for the marble producing companies to find the production profitable.[26]. Predominantly, the marbles are Calcitic, but white to grey dolomite occur as layers within the calcite marbles or as bordering units. The latter has, until now, not been of significant interest as building stone. Several types of commercial marble occur in the area,These include fine to medium-grained, graphitic grey marble with white bands, medium- to coarse-grained white marble with grey bands and several subordinate types such as pink, silicaterich marble, pure white, fine-grained marble and sky blue to green marble[26].

The stone has played significant role in human endeavors since earliest recorded history. A metamorphic rock type, Marble ranks the largest produced natural stone in the world and it accounts for 50% of the world's natural stone production [5].The industry involves mines, processing plants, cutters for the production of tiles for walls and floors, household articles. In Ethiopia there is no a trend in using marbles as coarse aggregate but universal approaches shown these material have a quality to replace the conventional aggregate that taken as a full practice[5].

H. Hebhoub , H. Aoun , M. Belachia , H. Houari and E. Ghorbelstated that An experimental approach to substitute natural aggregate by the waste marble aggregates; the concern is more scientific than economical and environmental. The result obtained demonstrated the performance of various concrete mixtures which may help to understand the behavior of these aggregate. Therefore, the orientation of this research has shown that setting certain parameters has identified the best percentage of substitution for each type of aggregate. Analysis of these results has revealed that the appropriate of marble waste aggregates can lead to interesting characteristics in terms of strength, indeed the use of marble aggregate resulted in a considerable increase in the compressive and tensile strength[19].

CHAPTER THREE

MATERIALS AND RESEARCH METHODOLOGY

3.1 General

The study methodology was lead to accomplish the research objectives. The first activity in this research was review literatures related to the research from different sources like: text books, research papers, journals, magazine, internet, etc.

Then, laboratory experimentations have been carried out. So, in order to obtain the final results, first concrete making materials preparation and testing have been performed. Then, based on the test results concrete making materials proportioning have been executed and mix-design was prepared for C-25 concrete grades. After that, with the provided mix proportion, mixing of ingredients has been performed .Then, the prepared concrete samples have been tested for both in the fresh and hardened states. For the fresh state workability property of concrete has been checked and for hardened concrete compressive and flexural strength tests have been carried out at ages of 7th, 14th, and 28 days.

The results obtained from experiment have been discussed and presented in tables and figures. Finally, conclusions were drawn and recommendations have been forwarded

3.2 Study Area

The study area of this research was in Jimma Town. It is one of the ancient and largest towns in the country which located 335km by road southwest of Addis Ababa. Its geographical coordinates are approximately $7^{o}41'$N latitude and $36^{o}50'$E longitude. The town is found in an area of average altitude, of about 5400ft (1780 m) above sea level. It is a special zone of the Oromia Region and which is surrounded by Jimma Zone.

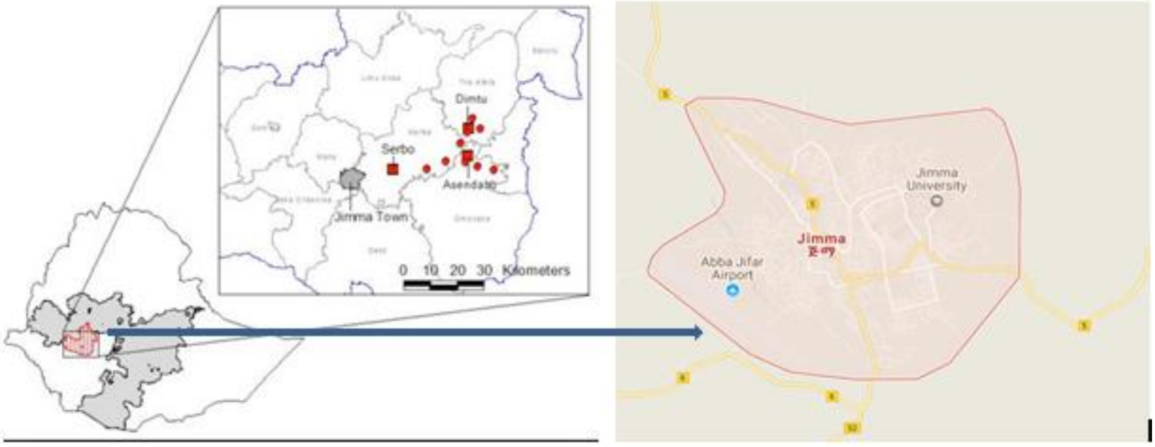


Figure 3.1: Map of the Study Area

3.3 Study Period

The research has taken seven months and it was started on April 2017 and it was ended on October 2017, which was including from data collection up to the final paper submission.

3.4 Study Design

Experimental design was used for this research during the study period; in order to provide the most reliable proof by studied the quality of the raw material of concrete mainly suitability of different types of coarse aggregate; waste ceramic and marble tiles. With this design the exact and important information was gained about effects of coarse aggregate type on workability, compressive and flexural strength of concrete C-25.

3.5 Population

The study populations was conventional concrete coarse aggregate; namely crushed basaltic stone and waste white paste ceramics tile aggregate and waste white/dirty white color marble tile aggregate which was found from JIT staff condominium maintenance work and in JIT compound.

3.6 Sample Size and Sampling Procedure

The sample sizes that have from the study are just the representative samples size at different types of coarse aggregates. For different curing days independently three samples took for both compressive and flexural strength test with six different types of mixes and this summarized as 54 cube specimens and 54 flexural specimens with a percentage quantity of coarse aggregates 216.187kg,140.32 kg and 142.065kg for control basaltic coarse aggregate ,waste marble and waste ceramics tile coarse aggregates respectively. Samples were taken from ceramics and marble waste tiles from Jimma University, JIT compound, and JIT staff condominium maintenance and renovation works as wastes and by manual crushing of hammer with a considerable approximate size of maximum 37.5mm.River Sands of worabe for both control and trial experiments and basaltic coarse aggregate from Jimma town was taken for experimental study with a given mix design.

The sampling technique used for this research was a non-probability sampling technique which is the purposive method. This sampling technique was proposed based on the information that the researcher have and the aim or goal of the researcher to be achieved.

3.7 Study variable

3.7.1 Dependent variable

- ❖ Suitability of waste ceramic tile and waste marble tile as a coarse aggregate in C-25 concrete

3.7.2 Independent variable

- ✓ Aggregate Gradation
- ✓ Specific gravity
- ✓ Flexural strength
- ✓ Compressive strength
- ✓ Water Absorption capacity
- ✓ Moisture content of aggregate
- ✓ Mix ratio for coarse aggregates

3.8 Sources of Data

Both primary data sources and secondary data sources were 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 were laboratory experimental output.

3.9 Laboratory Experimental Works Procedure

Stage 1:- Sampling preparation stage

- ❖ Coarse Aggregate: - For necessary concrete mixes by basaltic crushed stone, the same coarse aggregate taken from "varnero crushing plant crushed stone "was used. This aggregate type is commonly used in the Jimma Town area .Using a single type of coarse aggregate ensured that any variations in concrete properties were not due to this material.

White paste waste ceramic tiles and white colored waste marble tiles crushed manually with a hammer by guesting towards the nominal maximum size of coarse aggregate at a laboratory

- ❖ Fine Aggregate (Sand) :-Worabe Sand sample prepared for both sand property tests and for concrete mix, after checking out the silt content the un-washed sand sample was taken

Stage:-2: Laboratory tests on constituent of concrete

- ➢ Tests on coarse aggregate according to ASTM 136,ASTM C 127, ASTM C 29/C 29M,ASTM C-131 and BS Standard Procedures. (i.e. sieve analysis or gradation, water absorption, specific gravity, moisture content, unit weight, abrasion resistance)
- ➢ Tests on fine aggregate according to ASTM 136, ASTM C 128,ASTM C 29/C 29M,ASTM C 29/C 29M and BS Standard Procedures. (i.e. sieve analysis or gradation, water absorption, specific gravity, moisture,unit weight ,content bulking of sand and Silt/Clay Test of Sand sample).

Stage:-3: Concrete mix design and Mixing of concrete

1. Prepared C-25 Concrete Mix-Design for samples according the ACI Methods: the control 100% basaltic stone crushed coarse aggregate and other concrete constituent with their relative proportions and according to ACI mix design process as follows:

To the extent possible, selection of concrete proportions was based on test data or experience with the materials actually to be used. Thus the following information for available materials was useful:

- ✓ Sieve analyses of fine and coarse aggregates.
- ✓ Unit weight of coarse aggregate.
- ✓ Bulk specific gravities and absorptions of aggregates.
- ✓ Specific gravities of ordinary Portland cement
- ✓ Optimum combination of coarse aggregates to meet the maximum density gradings, and by using the following procedures the mix design was implemented

The Procedures of ACI mix design were: as follows

Step-1: Choice of slump

Step-2: Choice of maximum size of aggregate

Step-3: Estimation of mixing water and air content

Step-4: Selection of water-cement or water-cementitious materials ratio

Step-5: Calculation of cement content

Step-6: Estimation of coarse aggregate content

Step-7: Estimation of fine aggregate content

Step-8: Adjustment for moisture aggregate

Step-9: Trial batch adjustments

2. Scrubbed with oil the inner parts of the molds of specimen of cubes and flexurals that aid the specimen to be not scratched.

Figure 3.2: A and B shown scrubbing the mold with oil and mixing the ingredients respectively

3.Mixing of concrete by different percentage content and interchangeable(substitutable) coarse aggregate type;100% crushed basaltic stone for control, 50% waste ceramics tile and 50% waste marble tile,75% waste ceramics tile and 25% waste marble tile and vice versa,75% basaltic aggregate 25% waste ceramics tile and 75% basaltic stone and 25% waste marble tile, but Cement, fine aggregate(sand) and water are constant for all C-25 concrete mix. For this at least three cubes of 150 x 150 x 150 mm, three flexural 10*10*50mm and also for slump test of concrete have been made for consecutive test days 7th, 14th and 28th respectively.

4. The slump test was done in order to check the workability of the concrete and also prepared three samples of concrete cubes and three samples of flexural were casted from different types and percentages of coarse aggregate and three cubes and three flexural within a days of 7th, 14th and 28th in a single percentage samples; totally fifty six cubes and fifty six flexural samples were casted by using 150mm*150mm*150mm cubic and 10*10*50 flexural cast respectively within a week.

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Figure 3.3;A and B shown the slump cone test of concrete workability

Figure 3.4;A and B shown concrete cube sample production in the laboratory

- De-molding Specimen and coding (identification) the sample concrete cubes and flexurals

Removing the cubic and flexural mold with a great care to prevent any damage, external and internal, to the specimen as shown in figure 3.6 (a).

Figure 3.5;A and B samples of cube and coding the samples respectively

After that Coding the concrete cube and flexural samples based on control sampleand percentage of coarse aggregate typewas categorized as samples 1 to 6. Which means: Sample 1(Normal basaltic sample) contained naturally 100% crushed basaltic stone coarse aggregate as(controlled Sample) with (NBS1, NBS2 AND NBS3 cubes and flexurals), Sample 2 (Ceramics and Marble tile sample) contained 50% waste ceramics tiles and 50% waste marble tile coarse aggregates (C=MS1, C=MS2 AND C=MS3 cubes and flexurals), sample 3(Normal basaltic and ceramics tile samples) contained 75% normal basaltic crushed stone aggregate and 25% waste ceramic tile coarse aggregate (BCS1, BCS2 AND BCS3 cubes and flexurals), Sample 4 (Normal basaltic and marble tile samples) contained 75% normal basaltic crushed stone aggregate and 25% waste marble tile coarse aggregate (BMS1, BMS2 AND BMS3 cubes and flexurals),sample 5(Ceramics and marble tile samples)contained 75% waste ceramics tile coarse aggregate and 25% waste marble tile coarse aggregate (CMS1,CMS2 AND CMS3 cubes and flexurals),sample 6(marble and ceramics tile samples) contained 75% waste marble tile coarse aggregate and 25% waste ceramics tile coarse aggregate (MCS1,MCS2 AND MCS3 cubes and flexurals) and a number that describes after abbreviations 1,2 and 3 represents the days of curing at seventh, fourteenth and twenty eighth respectively and cured samples in the provided curing tanker at the laboratory.

Stage -4: Compressive and flexural strength tests of concrete specimens

Stage-5: Analysis and discussion

1. Compare and contrast of the quality and suitability of the coarse aggregate samples, discussed on the effect of properties of coarse aggregate on C-25 concrete ,workability, unit weight, compressive strength and flexural strength of the concrete.

2. Analysis and discuss the result by using Tables, Bars, Charts and Graphs.

3.10Material Preparation, Mix Design and Concrete Production

3.10.1 Material preparation

The physical characteristics of concrete making materials (Cement, fine aggregate, Coarse aggregate and Water) used for the research were examined and appropriate mix design was made.

3.10.1.1Cement Used For the Experiment

Type of Cement used in the concrete mix was ‘Dangote’- Ordinary Portland cement (OPC) whose Cement Grade 42.5R which is local available cement. ‘Dangote’ was decided upon as the most suitable cement type. Since it is widely used in the construction industry at the current time, it will better simulate normal construction practices.

3.10.1.1.1 Properties of cement

Commercially available Ordinary Portland Cement (OPC) Dangote 42.5R Cement Grade and specific gravity of 3.15 was used throughout the experiment. As the sieve test result shown 94.4% of its weight passed through 75µmm sieve and according to Ethiopian standard up to 10% the weight of residue left on the sieve of the total cement it is treated as ordinary Portland cement

3.10.1.2 Aggregates Used For the Experiment

Aggregates are materials basically used as filler with binding material in the production of concrete. Aggregates form the body of the concrete, reduce the shrinkage and affect economy. Therefore, it is significantly important to obtain right type and quality of aggregates on site. They should be clean, hard, strong, and durable and graded in optimum size to achieve utmost economy from the paste. Therefore, to judge the quality of the aggregate physical characteristics tests have to be conducted. As a main point of view this research studied the suitability of different types of coarse aggregates for concrete mix by testing and comparing the economy of the overall concrete production by different types of coarse aggregate. Thus, in this research the following physical testes are performed on the properties of fine and coarse aggregate.

3.10.1.2.1 Properties of fine aggregate

The natural river sand is taken for all control and experimental samples for concrete production. The fine aggregate used for the experiment was worabe sand, which originates from worabe silte zone, southern Ethiopia , which is 343 km from Jimma town and it is one of the main supply for the construction industries at jimma town. The fine aggregates were dried and surface dry (SSD) state before any test was carried out. In addition to this, all fine aggregate which retain on 9.5mm sieve size were no longer relevant, and all the passing fine aggregate were used for experimentation. Then, the following tests were conducted for worabe river sand.

A.Silt Content

According to the Ethiopian Standard it is recommended to wash the sand or reject if the Silt/Clay content exceeds a value of 6%. From the test result obtained, the Silt/lay content of the sand used for this experiment before washing was 4.5%, which is under the maximum requirement of Ethiopian standard. This show that worabe sand sample with in satisfactory limit and it was accepted sand type for construction purpose.

B. Sieve Analysis

The sieve analysis test of the sand sample was done according to ASTM 136 in two trial tests, therefore the gradation result of Worabe sand sample was laid over zone 2. Thegrading requirements according to ASTM C 33 and BS as well as the percentage passed of the worabe sand sample have been shown Figure 3.1 below.

Table 3.1 Fine aggregate gradation test result with zoning and ASTM limit standards

	Cumulative % Retained		Cumulative Percent Passing		Percentage Passing Zone								ASTM Standard C33-78
					Zone 1		**Zone2**		Zone 3		Zone 4		
Sieve Size mm/in	Trial 1	Trial 2	Trial 1	Trial 2	Min.	Max.	**Min.**	**Max.**	Min.	Max.	Min.	Max.	
9.5 (#3/8)	0	0	**100**	**100**	100	100	**100**	**100**	100	100	100	100	**100**
4.75(#4)	9.75	8.85	**90.25**	**91.15**	90	100	**90**	**100**	90	100	95	100	95-100
2.3(#8)	23.5	22.8	**76.5**	**77.2**	60	95	**75**	**100**	85	100	95	100	**80-100**
1.18(#16)	41	37	**59**	**63**	30	70	**55**	**90**	75	100	90	100	**50-85**
0.6(#30)	57	59	**43**	**41**	15	34	**35**	**59**	60	79	80	100	**25-60**
0.3(#50)	71	76	**29**	**24**	5	20	**8**	**30**	14	40	15	50	**10-30**
0.15(#100)	91.5	92.5	**8.5**	**7.5**	0	10	**0**	**10**	0	10	0	15	**2-10**

0.075(#200)	98.5	99.05	1. 5	0.95									
Pan	100	100											
	293.75	**296.15**											

The above table shown that, the sand sample was moderate near to coarser Sand.

The fineness moduless of fine aggregate was computed by using equation 1 for both trial one and two from sieve analysis and the result was 2.93 and 2.96 repectively,which shows the fine aggregate sample is coarser while it was between 2.9-3.2 and the worabe sand sample was zone two,according to Crag R.F. (2004) stated that when the percentage pass on 600µm sieve size is (35-59) % then it is Zone-2, while the trial samples were 43% and 41% respectively passed on 600µm sieve size, therefore this also show that the samples are Zone-2

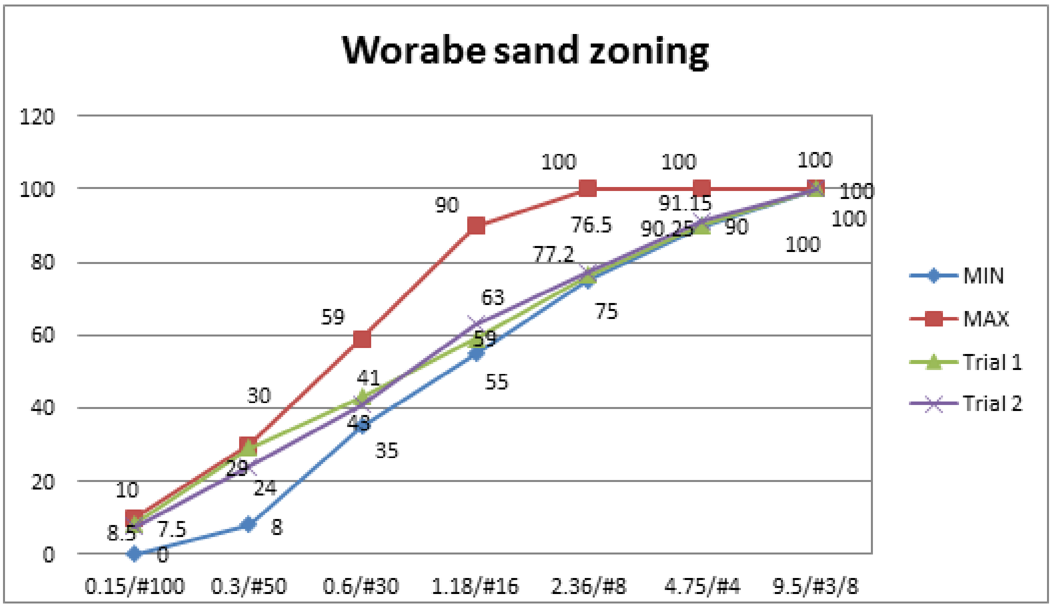


Figure 3.6 Chart for worabe sand sample zoning and Gradation with ASTM limit

A detailed sieve analysis of the worabe sand sample was found in appendix-1 in Table 1A ,1Bacoording to ASTM and BS limit and the grading curve was showed in 1A according ASTM. Fineness Modules for sand samples were 2.93 and 2.96 for independent two trial, which was a coarser fine aggregate while it is between 2.9-3.2 and it was satisfactory.

C. Summarized Physical Properties of Worabe Sand sample

The following table 3.2 discussed and summarized the types of tests and the test results of Worabe sand sample executed in the concrete making material laboratory

Table 3.2: worabe sand sample summarized physical properties

Source of sample	Material type	Types of test		Test result
Worabe	Sand(fine aggregate)	Unit weight	Compacted	1608.6
			Loose	1506.9
		specific gravity (saturated surface basis)		2.56%
		Water Absorption Capacity		1.09%
		Moisture Content		1.42%
		Fineness Modules		2.938 and 2.96 in two trial test
		Silt/Clay content		4.5%
		Zone		II

3.10.1.2.2 Properties of coarse aggregates

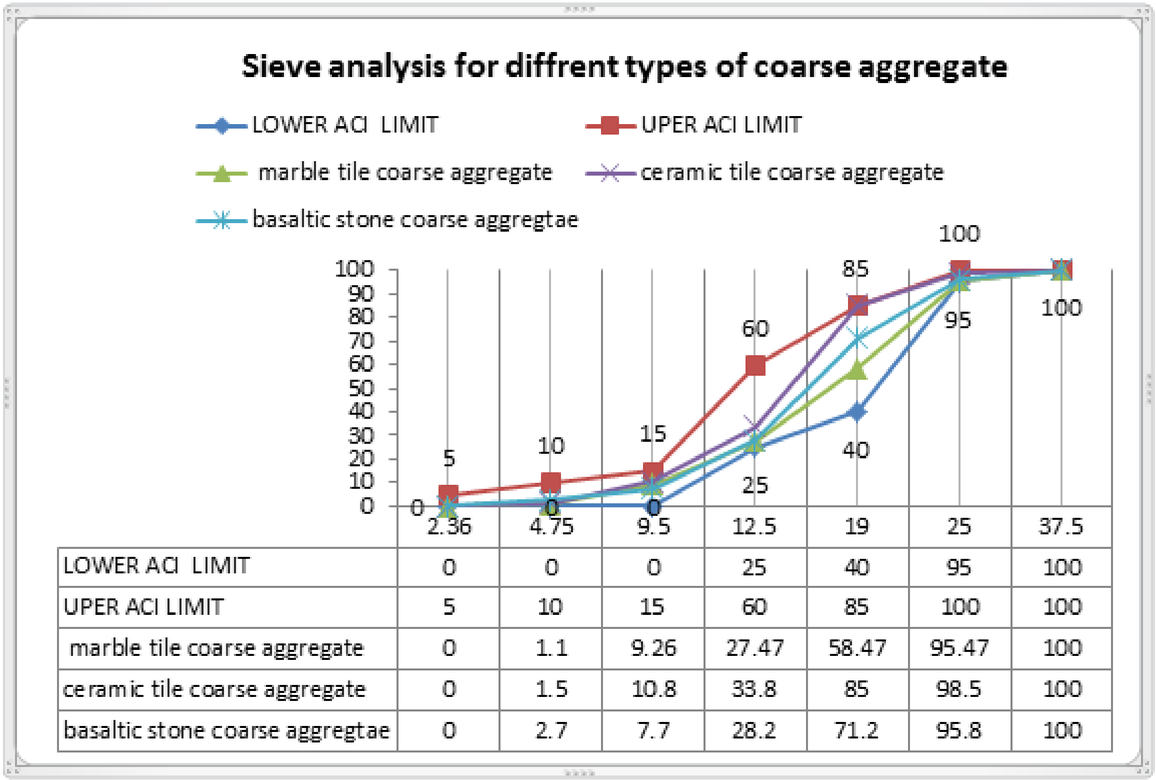
The coarse aggregate used for this research was basaltic crushed rock took from varnero crusher plant with a maximum aggregate size of 37.5, and waste ceramics and marble tiles took from the site called JimmaInstitute of Technology (JIT) staff condominium maintenance and renovation work and in JIT,jimma university compound, those aggregate materials crushed manually by hammer in maximum approximated size of 37.5.

Figure 3.7: A, B, and C coarse aggregate types for the laboratory experiment as samples

A. Sieve analysis

For individual sample sieve analysis 10kg of coarse aggregate was prepared and with the help of mechanical sieve shaker machine and in manual manner , by using square opening ACI coarse aggregate sieve, from 37.5-2.36mm sieve the test was executed.

According to the sieve analysis result all three kinds of aggregate were satisfied the limit of upper and lower ACI sieve parameter in maximum size of 37.5 and nominal aggregate size of 25.



	2.36	4.75	9.5	12.5	19	25	37.5
LOWER ACI LIMIT	0	0	0	25	40	95	100
UPER ACI LIMIT	5	10	15	60	85	100	100
marble tile coarse aggregate	0	1.1	9.26	27.47	58.47	95.47	100
ceramic tile coarse aggregate	0	1.5	10.8	33.8	85	98.5	100
basaltic stone coarse aggregtae	0	2.7	7.7	28.2	71.2	95.8	100

Figure 3.8:summerized sieve analysis for different types of coarse aggregate

B. Physical Properties of Different Types of Coarse Aggregate Samples

The following table 3.3 discussed and summarized the physical properties of Varnero crushed basaltic stone, marble and ceramic tile coarse aggregates while they executed tests and recorded the results. And all types of coarse aggregates are within the limit of coarse aggregate criteria to be a constituent of concrete production

Table 3.3: Physical characteristics and properties of different types of coarse aggregates summary

Source of sample	Material type	Types of test		Test result	
Jimma(varnero crusher plant)	Basaltic coarse aggregate	Unit weight	Compacted	**1630.5**	
			Loose	**1517.5**	
		specific gravity (saturated surface basis)		2.73%	
		Water Absorption Capacity		1.74%	
		Moisture Content		2.04%	
		Fineness Modules		7.185	
		Size of aggregate		Maximum	Nominal
				37.5	25
Jit staff condominium and maintenance work jitcompound,jimma university	Waste white paste ceramics tile coarse aggregate	Unit weight	Compacted	**1530.11**	
			Loose	**1416.53**	
		specific gravity (saturated surface basis)		2.565%	
		Water Absorption Capacity		0.94%	
		Moisture Content		2.04%	
		Fineness Modules		7.027	
		Size of aggregate		Maximum	Nominal
				37.5	25
Jit staff condominium and maintenance work jitcompound,jimma university	Waste white colored marble tile coare aggregate	Unit weight	Compacted	**1500.01**	
			Loose	**1444**	
		specific gravity (saturated surface basis)		2.703	
		Water Absorption Capacity		0.95%	
		Moisture Content		1.52%	
		Fineness Modules		7.3107	
		Size of aggregate		Maximum	Nominal
				37.5	25

3.10.1.3 Water Used For the Experiment

Mixing water used for all the mixes in this research was drinkable water (potable water) obtained from jit,Jimma University, Material Laboratory, water supply.

3.10.2 Concrete Mixes

3.10.2.1 Concrete Mix Design and Materials Proportion

In this research work, the ACI Method of concrete mix design was used to design C-25 concrete grade having a minimum strength of 25 Mpa with 28 days curing and a water cement ratio of 0.61 since the required minimum strength is 25 Mpa at 28 days and in non-air entrained condition. On this base; six different types of concrete mixes were prepared based on coarse aggregate type and aggregate percentage proportions, those are one concrete mix prepared for the normal crushed basaltic stone coarse aggregate samples used as a control and the others are substitution in different percentage and fully substitution by the experimental coarse aggregates without any admixtures

The quantity of concrete materials was calculated by using the physical properties of the materials and Table 3.4 show the quantity of materials for one cubic meter for C-25 concrete grade. The Standard cast iron molds of size 15x15x15cm are used in the preparation of concrete cubes for compressive strength tests.

Table 3.4: The quantity of concrete ingredients for 1m3 by ASTM mix design criteria

Types of sample mix	Ingredients	Percentage	mass	Remark
Normal basaltic stone coarse aggregate(NBS)	Water (potable)	100%	170.9	All masses are a multiplication product of ingredients quantity gained by factor characteristics during material properties study and mix percentage proportions from mix design except cement
	Cement(opc grade…)	100%	292	
	Fine aggregate(worabe sand)	100%	812.3	
	Normal basaltic stone coarse aggregate	100%	**1147.65**	
Total			**2422.85**	
75% crushed basaltic and 25% marble tile coarse aggregate(BMS)	Water (potable)	100%	171.38	
	Cement(opc grade…)	100%	292	
	Fine aggregate(worabe sand)	100%	831.4475	
	Normal basaltic stone coarse aggregate	75%	1126.75	
	Waste marble tile coarse aggregate	25%		
Total			**2421.5**	
75% crushed basaltic and 25% ceramic tile coarse aggregate(BCS)	Water (potable)	100%	169.8	
	Cement(opc grade…)	100%	292	
	Fine aggregate(worabe sand)	100%	829.55	
	Normal basaltic stone coarse aggregate	75%	1130	
	Waste ceramic tile coarse aggregate	25%		
Total			**2421**	
75% waste marble tile and 25% ceramic tile	Water (potable)	100%	171.23	
	Cemen(opc grade…)	100%	292	
	Fine aggregate(worabe sand)	100%	886.99	

coarse aggregates(MCS)	Waste marble tile coarse aggregate	75%	1067.3	quantity: the aggregate property varies the demands of water and fine aggregate quantity in fixed cement quantity manner.
	Waste ceramic tile coarse aggregate	25%		
Total			**2417.5**	
75% Waste ceramic tile and 25% waste marble tile coarse aggregates(CMS)	Water (potable)	100%	168.05	
	Cement(opc grade…)	100%	292	
	Fine aggregate(worabe sand)	100%	883.1975	
	Waste ceramic tile coarse aggregate	75%	1073.93	
	Waste marble tile coarse aggregate	25%		
		Total	**2417.1**	
50% Waste marble tile and 50% waste ceramics tile coarse aggregate (M=CS)	Water (potable)	100%	169.645	
	Cement(opc grade…)	100%	292	
	Fine aggregate(worabe sand)	100%	885.09	
	Waste marble tile coarse aggregate	50%	1070.63	
	Waste ceramic tile coarse aggregate	50%		
Total			**2417.365**	

3.10.2.2 Concrete mixing and Production Process

The concrete test specimen cube and flexural molds and large tray were cleaned from all dust and the concrete molds coated with releasing agent (oil) to smooth the surface and to prevent sticking of mixed concrete with the mold. The ingredients, such as; cement, fine aggregate (sand), coarse aggregate and water were measured to an accuracy of 0.1g balance. After that the weighted coarse aggregate in required percentage proportion, coarse aggregate was first added on the large flat tray and the fine aggregate was added after the coarse aggregate and mixed together and then the cement is added next to fine aggregate and dry mixed for a minute. Then, water was added to the dry mixed concrete ingredients mixture and thoroughly mixed for two more minute.

The mixed concrete was checked for workability by filling the standard slump cone with three layers by rodding each layer with 25 times according to ASTM C-143.Between each mix, the tools was cleaned using tap water to ensure that there was no contamination between the mixes.

3.10.2.3 Casting

Proportionally mixed concrete was placed in the molds of cubes and flexures after the slump was checked for different types of concrete mixes. During the casts of concrete, compaction was executed in three layers with the help of a tape rode, by rodding each layer with 25 times. For each mix, were prepared three cube molds having

(150mmx150mmx150mm) size and three flexures having (100mmx100mmx500mm) were nominal compulsory; thus, were casted for compressive and flexural strength testing.

3.10.2.4 Curing

The concrete mix was casted in the molds for the first 24 hours. After that, the concrete was removed from the molds and placed in a water bath at a temperature of 23 ± 1^{o}C for curing to take place until the testing age was reached in the anticipated curing age.

3.10.2.5 Compressive and flexural strength testing of the concrete specimen

In the seventh,fourteenth and 28 days of curing period the concrete cubes specimens was removed from the water bath then placed in dry surface until the specimens was surface dried and after that weighted concrete cubes specimens in order to determine the density and unit weight of the concrete cube and beam. Finally, the specimens was tested by compression testing machine and flexural testing machine. Loading Rate for 150 mm cube was 140 kg/cm2 per minute till the Specimens fails for cube test.

Figure 3.9:-A and B shown in stage of compressive strength test of concrete cubes

CHAPTER FOUR

RESULT AND DISCUSSION

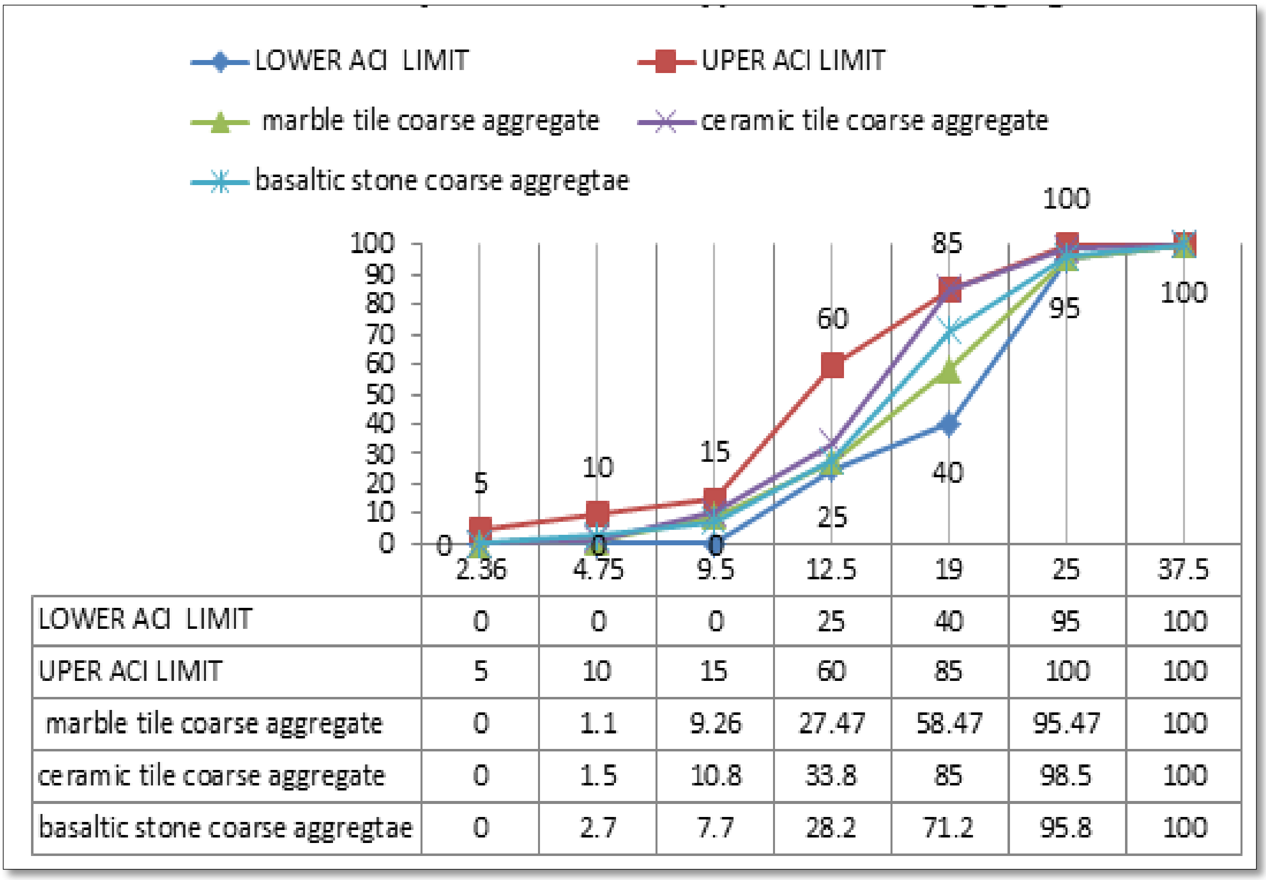
4.1 Coarse Aggregates Properties

The suitability of the coarse aggregates sample for mix design was examined accordingly with the properties of coarse aggregate tests.in this research, as a main concern coarse aggregate in the mix design was shown its own characteristics and had its own influence on the hardened concrete, thus this document described important coarse aggregate properties by identifying considerations with the relative test result value as follows;

4.1.1 Sieve Analysis

The test was oriented by ACI –C-136 standard test method for sieve analysis of fine and coarse aggregates. This test method is used primarily to determine the grading of materials proposed for use as an aggregate is within the parameter or not. The results are used to determine compliance of the particle size distribution with applicable specification requirements and to provide necessary data for control of the production of various aggregate products and mixtures containing aggregates. Based on the above regard, the results for the sieve analysis test on the coarse aggregates are shown in Figures 4.1. The grading curve for the aggregates falls within the lower and upper limit of the grading requirement for all coarse aggregate types' aggregate namely basaltic course aggregate which was appeared as a control, waste marble and ceramic tile coarse aggregates. This implies that the aggregates are satisfied the acceptance criteria for production of C-25 concrete in gradation manner. The waste materials sieve analysis was appeared similar to the basaltic coarse aggregates which is aiding the constructions sector by now.

The fineness modules result of different coarse aggregates were,7.185, 7.027 and 7.3107 for basaltic coarse aggregate, waste ceramics and marble tile coarse aggregates respectively while the range for fineness modules of coarse aggregate is not much important to describe since the sieve analysis reported positively, besides, according to ACI the fineness modulus of coarse aggregate is executed if there is some exceptional proportioning method, but the waste marble tile coarse aggregate was the coarser aggregate from other types ,while it crushed with hammer in existence of 2 cm thickness as a whole.



	2.36	4.75	9.5	12.5	19	25	37.5
LOWER ACI LIMIT	0	0	0	25	40	95	100
UPER ACI LIMIT	5	10	15	60	85	100	100
marble tile coarse aggregate	0	1.1	9.26	27.47	58.47	95.47	100
ceramic tile coarse aggregate	0	1.5	10.8	33.8	85	98.5	100
basaltic stone coarse aggregtae	0	2.7	7.7	28.2	71.2	95.8	100

Figure: 4.1 Sieve analysis test result for different types of coarse aggregates

4.1.2 Specific Gravity and Other Important Properties of Coarse Aggregates

Specific gravity and other Important properties of Coarse Aggregates are summarized in the below table as follows;

Table 4.1:Physical property test result of different types of coarse aggregates

Properties	Basaltic coarse aggregate	Waste white colored marble tile coarse aggregate	Waste white paste ceramic coarse aggregate	Fine aggregate
Specific gravity	2.73%	2.703%	2.565%	2.56%
Absorption	1.74%	0.95%	0.94%	1.09%
Moisture content	2.04%	1.52%	2.04%	1.42%
Compacted unit weight	1630.5	1500	1530.11	1608.6
Ratio of loose unit weight to compacted	0.93	0.96	0.925	0.936

unit weight				

The specific gravity, absorption and unit weight of the crushed basaltic stone coarse aggregate sample was higher than the other two coarse aggregate types, as shown in the table 4.1, it relatively increases about 0.027% and 0.165% by specific gravity from waste marble and ceramics tile coarse aggregates respectively. Absorption of basaltic coarse aggregate was higher with about 0.79% and 0.8% from waste marble and ceramics tile coarse aggregates respectively. Therefore, the water absorption of white paste ceramic tile and marble tile coarse aggregate were very low. The test result shown that the waste white paste ceramics tile coarse aggregate and crushed basaltic stone was 2.04 % while moisture content was examined by being greater than that of waste marble tile coarse aggregate about 0.52 %.

In unit weight examination in loose and compacted manner crushed basalt stone was recorded the higher value rather than the others by about 130.5kg/m3 and100.39kg/m3 from waste marble and ceramic tile coarse aggregates respectively. Such situation shows white marble tile and white paste ceramic tile coarse an aggregate have capacity to produce light weight concrete rather than basaltic coarse aggregate. The above sample test result shows the coarse aggregates were in acceptable or suitable manner to produce normal concrete with their properties limit. Most natural aggregates have relative densities between 2.4 and 2.9 with corresponding particle (mass) densities of 2400 and 2900 kg/m3.The waste materials are within the limit of corresponding particle relative density, which allows them to be a participant in concrete mixture as a coarse aggregate.

The rodded bulk density limits of aggregates used for normal weight concrete generally ranges from 1280 to 1920 kg/m3.therefore the mix design was prepared and proportioning of ingredients was held with the ACI mix design method by referring the state and limitation of the aggregate properties to create normal C-25 concrete.

4.2 Concrete Mix Ratio Analysis and Discussion

The mix ratio for concrete mixes as listed in the below table 4.2,was implemented by inspecting the physical properties of the coarse aggregates and other constituents. With the fixed water cement ratio and adjustment of moisture, the mix ratio for different blended coarse aggregate type with ACI mix design method the following ratio result was examined.

Table 4.2:Concrete mix ratiofor 1m^3 with different types of coarse aggregates

Types of sample mix	Ingredients	Percentage	Mass	Mass of blended coarse aggregate	Mix ratio
(NBS)	Water (potable)	100%	170.9		1:2.78:3.93
	Cement(opc grade42.5R)	100%	292		
	Fine aggregate(worabe sand)	100%	812.3		
	Normal basaltic stone coarse aggregate	100%	**1147.65**		
Total			**2422.85**		
(BMS)	Water (potable)	100%	171.38		1:2.84:3.85
	Cement(opc grade42.5R)	100%	292		
	Fine aggregate(worabe sand)	100%	831.4475		
	Normal basaltic stone coarse aggregate	75%	1147	1126.75	
	Waste marble tile coarse aggregate	25%	1064		
Total			**2421.5**		
(BCS)	Water (potable)	100%	169.8		1:2.84:3.86
	Cement(opc grade 42.5R)	100%	292		
	Fine aggregate(worabe sand)	100%	829.55		
	Normal basaltic stone coarse aggregate	75%	1147	1130	
	Waste ceramic tile coarse aggregate	25%	1077		
Total			**2421**		
(MCS)	Water (potable)	100%	171.23		1:3.03:3.65
	Cement(opc grade42.5R)	100%	292		
	Fine aggregate(worabe sand)	100%	886.99	1067.3	
	Waste marble tile coarse aggregate	75%	1064		
	Waste ceramic tile coarse aggregate	25%	1077		
Total			**2417.5**		
(CMS)	Water (potable)	100%	168.05		1:3.02:3.67
	Cement(opc grade42.5R)	100%	292		
	Fine aggregate(worabe sand)	100%	883.1975		
	Waste ceramic tile coarse aggregate	75%	1077	1073.93	
	Waste marble tile coarse aggregate	25%	1064		
			2417.1		
(M=CS)	Water (potable)	100%	169.645		1:3.03:3.66
	Cement(opc grade 42.5R)	100%	292		
	Fine aggregate(worabe sand)	100%	885.09		
	Waste marble tile coarse	50%	1064	1070.63	

	aggregate				
	Waste ceramic tile coarse aggregate	50%	1077		
Total			**2417.365**		

A concrete mix BMS and BCS have almost the same proportion of mix ratio like MCS, CMS and M=CS concrete mixesdetected. The consumption of fine aggregate was seen larger in MCS, CMS and M=CS concrete mixes rather than the other three mixes, relatively the coarse aggregate has seen at minimized level in these mixes. The BMS and BCS mix samplestaken reasonable quantities of blended coarse aggregates in order to produce their mixes.

4.3 Slump Test Analysis and Workability

During the fresh or plastic state of concrete mix, slump was executed to measure the workability ofconcrete. Asampleoffreshlymixedconcreteisplacedandcompactedbyrodding about 25 times in three layer inamoldshapedasthefrustumofacone which height is 300mm. The mold is raised which a height about300mm and the concrete allowed to subside.Theverticaldistance between the original and displaced position of the center of the top surface of the concrete is measured and reported as the slump of the concrete. A concrete mix, either produced at a ready mix plant or on site, must be made of the right amount of cement, aggregates and water to make the concrete workable enough for easy compaction, placing and sufficient hardened concrete strength for good performance. If the mix is too dry, then its compaction will be too difficult and if it is too wet, then the concrete is likely to be weak. The workability of concrete depends on the property of the ingredients. So for this research case, the slump test has been checked according to ASTM C 143.

A concrete from different types of coarse aggregate within a fixed water cement ratio and different quantity of aggregates was executed according to ACI mix design procedures and moisture adjustment was done by orientation of properties of ingredient material.

Table4.3: Slump from different coarse aggregate type and proportion

Type of concrete mix by different coarse aggregates	Slump in mm	Limits (mm)
NBS;Normal basaltic stone	71mm	50-100(medium)
C=MS;50% waste ceramic and 50% waste marble tile	94mm	50-100(medium)
BMS;75% basalt and 25% waste marble tile	61mm	50-100(medium)
BCS;75% basalt and 25% waste ceramic tile	77mm	50-100(medium)
CMS;75% waste ceramic and 25% waste marble tile	107mm	100-175(high)
MCS;75% waste marble and 25% waste ceramic tile	17mm	0-25(very low)

A concrete mix which hold waste marble tile coarse aggregate 75% and 25% of ceramic waste coarse aggregate shows a least slump mm which is 17%, and the higher slump was in CMS sample. The MCS mix design parameter which allow to used more fine aggregate rather than other mixes and absorption of aggregate highly affect the slump to be decreased with the fixed water –cement ratio and directly affect workability, whereas the BCS,C=MS samples of slumps were fall within the parameters of choice of slump in the mix design. The slumps within limits of 50-100mm stated as a medium and 100-175 stated as high which is suitable in between congested rebar’s, then all mixes exclude the MCS sample mix, they are suitable in their slump amount which allow workability in better approach

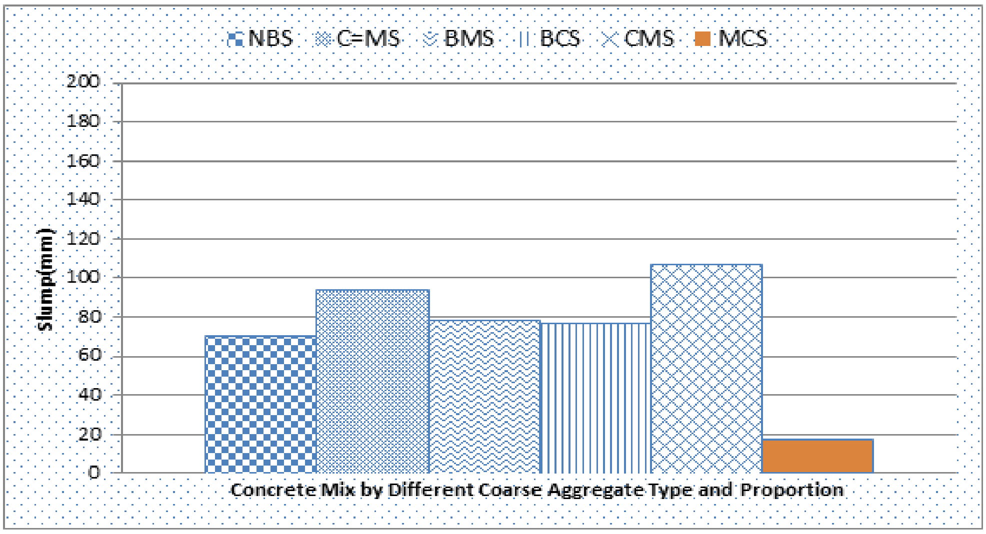


Figure 4.2: Slump from different coarse aggregate type and proportion

4.4 Compressive Strength Test Results and Discussion

It is known that compressive strength of concrete is highly dependent on water cement ratio and quality of ingredients beside other parameters; with the fixed water cement ratio and adjustment of moisture accordingly with the material properties, this research puts the result of compressive strength of concrete with different coarse aggregate types and percentage proportions by comparing in different curing days.

Table 4.4; Compressive strength test results of cubes at 7,14 and 28 days of curing

Types of mix sample	**Slump(mm)**	**Unit weight**	**Days of curing and average compressive strength in Mpa**			**Specified characteristics strength at 28 days**	**Target mean strength for M25 concrete**
			7 days	14 days	28 days	25	31.6
NBS	71mm		26.263	29.11	32.87	25	31.6
C=MS	94mm		23.096	24.78	26.98	25	31.6
BCS	61mm		25.725	28.977	33.11	25	31.6
BMS	77mm		26.433	31.07	35.68	25	31.6
CMS	107mm		22.526	23.933	25.76	25	31.6
MCS	17mm		26.077	27.633	29.78	25	31.6
						25	31.6

Concrete which hold 75% crushed basaltic stone and 25% of waste white colored marble tile coarse aggregate shows relatively better strength from those other proportions of coarse aggregate and the control 100% basaltic coarse aggregate concrete. On the contrary concrete which hold 75% of ceramics and 25 % of marble slightly weaker than the other concrete mixes and the control concrete.

From the expected 65% fulfillment as c-25 concrete in 7 days of curing all concrete mixes pass beyond 100% even from the specified characteristic strength of concrete at the ages of 28 days but C=MS and CMS concrete samples were passed the specified characteristic strength of concrete at the ages of 14 days at 7 days of curing. This means the concrete cube sample were passed from compressive strength expected 16.25 Mpa in 7th days, NBS,C=MS,BCS,BMS,CMS and MCS has been recorded as 161.61%,142.12,158.37,162.66,138.62 and 160.47% respectively. This shows all concrete mixes were good in their quality of ingredients and proper manner of proportioning has a significance role. And the BMS concrete mix shows relatively better development from other mixes (NBS,C=MS,BCS,CMS and MCS) in about 1.05%,20.54%,4.29%,24.04% and 1.92% respectively.

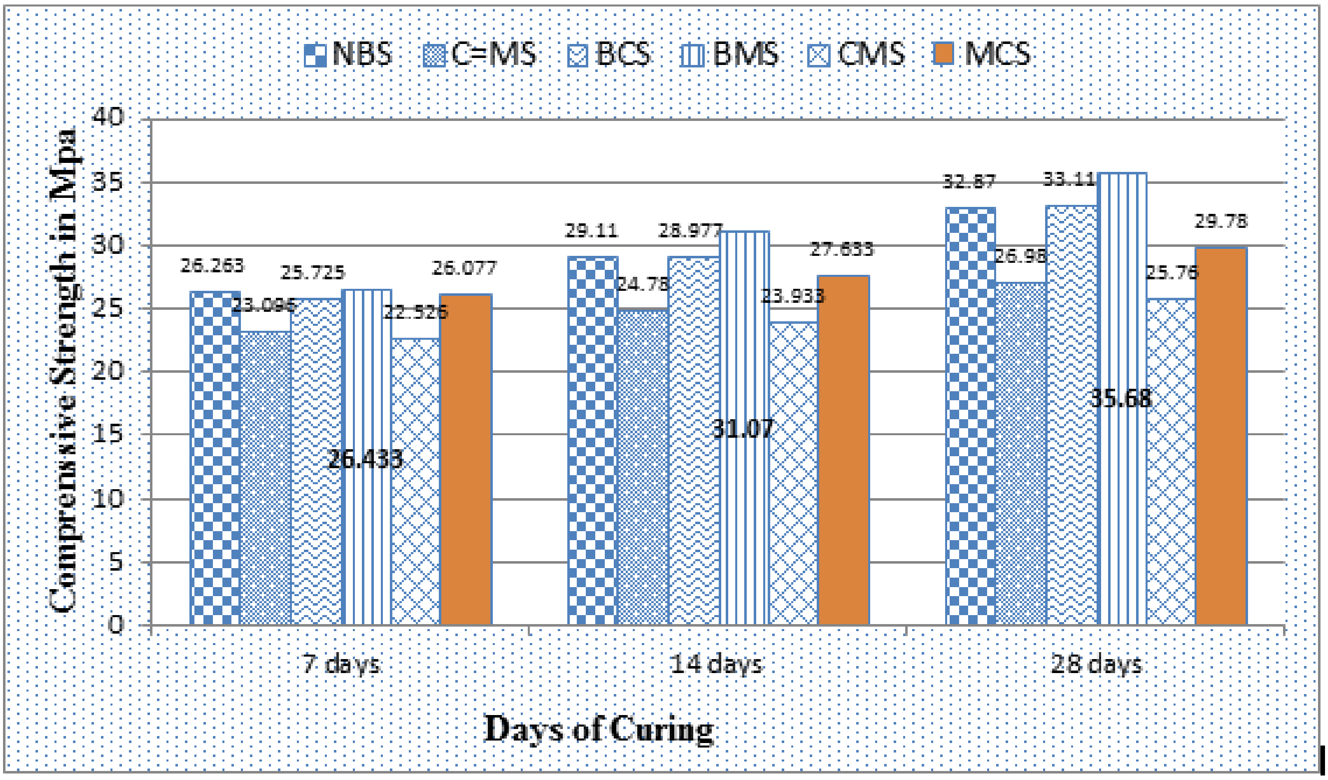


Figure 4.3; Compressive strength test results of cubes at 7, 14 and 28 days of curing

In fourteen days of curing from the expected percentage of curing of 90 from 28 days, all concrete mixes were passed beyond 100% and the BMS concrete cube sample also continued the better development of compressive strength rather than other mixes. The concrete cube samples (NBS, C=MS, BCS, BMS, CMS and MCS) have been recorded the strength 129.37%, 110.13%, 128.78%, 138.08%, 106.36% and 122.81% respectively. All concrete cubes were above the specified characteristics strength of 14 days and the BMS concrete mix shows relatively better development from other mixes(NBS,C=MS,BCS,CMS and MCS) in about 8.71%,27.95%,9.3%,31.72% and 15.27% respectively.

Concrete will gain its maximum strength at the curing ages of 28 days. Also this research executed experiments' of cube specimens of different coarse aggregate type and proportion of concrete mixes in universal testing machine. From the expected 100% of specified characteristics strength C-25 concrete mix means 25 Mpa, all specimens were passed and the BMS mix also continued its development rather than other mixes. The result shows NBS, C=MS, BCS, BMS, CMS and MCS has been recorded as 131.48%, 107.98, 132.44, 142.72, 103.04 and 119.12% respectively. All concrete cubes were above the specified characteristics strength of 28 days and the BMS concrete mix shows relatively better development from other mixes (NBS, C=MS, BCS, CMS and MCS) in about 11.24%, 34.74%, 10.28%, 39.68% and 23.6% respectively.

When the target mean strength was a parameter for acceptance criteria, the NBS cube specimen fulfill about 104%,and the others cube specimens(C=MS,BCS,BMS,CMS, and MCS) fulfills the strength(87%,104.627%,112.7%,81.51%,and 94.25%)respectively.

The BMS cube sample shown better strength of about 8.7 % from NBS and 8.073% from BCS samples. In all curing days i.e., in 7days, 14 days and 28 days the growth of BMS sample was recorded and the others were followed as BCS, NBS, MCS, C=MS and CMS respectively. Thus partial replacement of conventional coarse aggregate with 25% of waste white colored marble tile has shown significance growth in compressive strength at 28 days of curing beyond normal crushed basaltic stone coarse aggregate mixes. Secondly substitutions of 25% of waste white paste ceramic tile coarse aggregate with basaltic stone has shown slight development in strength rather than control mix normal basaltic stone coarse aggregate mix.

All concrete mixes which hold waste marble tile coarse aggregate recorded better strength than all concrete mix which hold waste ceramics tile coarse aggregate when they compared with their same proportion and substitution: ceramic tile smoothness was larger than that of marble tile, while the rougher the texture has the better bond strength with the paste, ceramics tile was weaker in creating better bond with the paste and the interfacial transition zone was weaker than that of marble tile coarse aggregate and they were flaky aggregate. Ceramic tile thickness for the intended experiments was within the limits of 0.6-1.2cm whereas the marble thickness was about 1.8-2.5cm.

4.5 Flexural Strength Test Results and Discussion

Concrete is known in its weaker strength of flexures. The test results have shown the sample flexural beams (50*10*10) cm with a one point load crushing value in the following table.

Table 4 .5:Flexural strength test results of cubes at 7,14 and 28 days of curing

Types of mix sample	Slump(mm)	Days of curing and average flexural strength in Mpa		
		7 days	14 days	28 days
NBS	71mm	4.21	4.875	5.26
C=MS	94mm	3.87	4.18	4.32
BCS	61mm	4.165	4.77	5.527
BMS	77mm	4.3	5.19	5.92
CMS	107mm	3.712	4.09	4.17
MCS	17mm	4.12	4.65	4.98

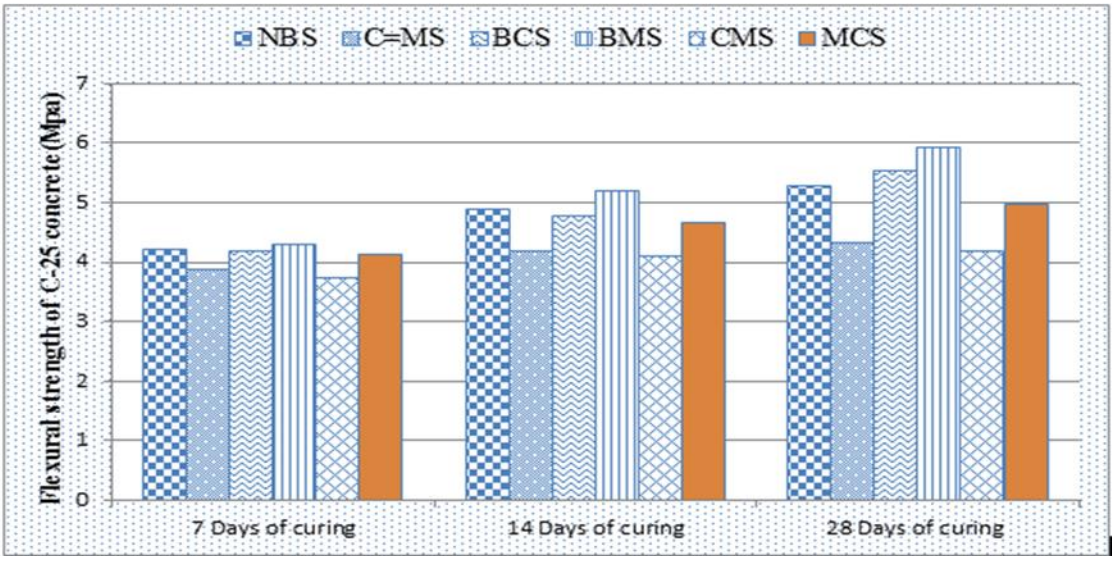


Figure 4.4: Flexural strength test results of cubes at 7,14 and 28 days of curing

As the above results shown the compressive strength of cube specimen BMS had a larger value from all other mixes including the control normal basaltic stone crushed aggregate, here in flexural strength the beam specimen BMS also shows a larger flex resistance value in all curing days execution.

The BMS sample shown 5.92Mpa strength that could be said better than the control mix in about 0.66Mpa.when the control specimen fulfill the flex resistance 100% as a parameter for other mixes comparison, the BMS specimen shown a about 112.14% strength growth which was better than control mix about 12.14%.not only the BMS sample, but the BCS sample also shown the second larger flex resistance by 105.07 %.Other samples(C=MS,CMS and MSC) fulfills the strength about 82.12%,79.27%, and 94.67% in 28 days of curing within the parameters of control mix respectively.

While studying the flexural strength it was known that it is to determine the resistance of concrete under bending stress and after that to determine the coefficient and demands of reinforcement bars for better strength. Thus this research puts the result of concrete flexural strength with different coarse aggregate types and proportions, and it is further can be used for the calculations and design of flexural demanded structure which need better strength from concrete mix design with different aggregate types and their proportions.as the result shows the substitution of 25% of marble coarse aggregate and secondly 25% of ceramic aggregate to the normal and conventional basaltic stone crushed aggregate can cause growth in flexural strengths too.

4.6 Unit Weight Result Analysis and Discussion

C=MS concrete mix of hardened concrete shows a minimum unit weight which was 2333.45kg/m3 from all concrete mixes while the density of concrete was examined in laboratory, consecutively CMS,MCS,BMS,BCS and finally the control NBS mixes in descending order with an average recorded value of 2353.7, 2361.98, 2415.66, 2425.22 and 2498.89 respectively. The result was shown marble and ceramics tile aggregates are very vital to reduce the unit weight of concrete to form structure. The C=MS has been reduced the unit weight of concrete from control mix about 165.44kg/m3.The unit weight of concrete mixes was highly dependent in coarse aggregate materials and mix design while other constituents and situation of mix environment stayed constant.

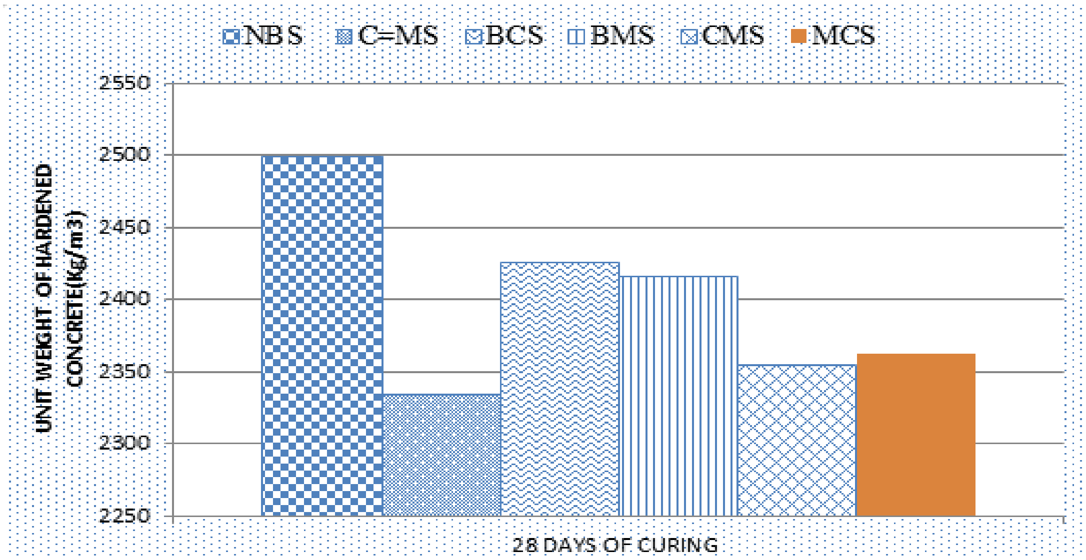


Figure 4.5: Average unit weights of 1m3 concrete by different types and proportions of coarse aggregates

The crushed basaltic and 25% replacement of waste marble tile coarse aggregate combination was ranked at third with its reduced unit weight and the first in compressive strength from all mixes, whereas the basaltic and 25% substitution of waste white paste ceramics tile coarse aggregate was ranked at fourth with its reduced unit weight and the second in its compressive strength at the curing ages of 28 days. Both mixes was better than the control 100% normal basaltic stone coarse aggregate sample in unit weight and compressive strength while light weightiness is a request.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

It has been examined the suitability of different types of coarse aggregate on c-25 concrete in the laboratory starting from reviewing the supportive and inspired literature reviewing up to the final out put on the workability, compressive and flexural strength of concrete.

The laboratory based research executed the study of different types of coarse aggregate namely waste white paste ceramics tile and waste white colored marble tile collected from JIT, Jimma University compound and JIT, staff condominium maintenance work as a waste and crushed manually to the approximate maximum size of 37.5 ASTM sieve and the control crushed basaltic stone coarse aggregate from varnero crusher plant; properties in the parameters of aggregate for concrete, quality requirement for aggregate in the mix design, engineering properties and their production process manner.

Coarse aggregates were tested accordingly with the methodology design of the research before mixing of concrete was performed. Sieve analysis, specific gravity, absorption, moisture content and unit weight were completed to check whether they are within the range of the coarse aggregate parameter for the concrete or not. After the property measured the mix design was prepared for six different samples with different proportions of three different coarse aggregate types with a same types of: cement opc grade 42.5 ,worabe sand and water. In the fresh state concrete mix was tested for the workability slump test and for the hardened state the concrete compressive strength in universal crushing machine and flexural beam test were executed. The tests were classified in 7th, 14th and the most important the 28th days ages of concrete strength test with the constant water to cement ratio 0.61. The results of the laboratory testing directed to the following conclusions:

1. Waste white paste ceramic and dirty white marble tiles showed almost the same properties to the crushed basaltic stone. The sieve analysis for all three coarse aggregate types including the control basaltic stone exhibited, they are suitable under a parameter of ASTM C-136 criteria to be a concrete constituent while they within 37mm maximum size and 25mm nominal maximum size upper and lower

limit of square opening sieve and showed almost the same fines modulus. The Specific gravity and compacted unit weight of coarse aggregates were with the limits of the criteria to be a concrete constituent, while the expected specific gravity is between 2.4-2.9, and the unit weight of aggregates for normal concrete generally ranges from 1280 to 1920 kg/m3.The lower compacted unit weight registered by waste marble tile which is 1500kg/m^3 but still it is very suitable for C-25 concrete production.

2. The coarse aggregate shape and textures have its own influence on the strength of concrete. Waste ceramics tile coarse aggregate has very smooth top side and flaky shape which inspires the crack begins between the paste and the aggregate (aggregate paste interface) this is very slight in waste marble tile coarse aggregate, the 75% ceramic tile coarse aggregate with 25% marble coarse aggregate shown the smallest compressive and flexural strength from all mix samples, which were 25.76 and 4.17 respectively however it is greater than the specified characteristics strength and lower than target mean strength of C-25 concrete at the ages of 28 days of curing on compressive strength test.
3. By inspecting the physical properties of different coarse aggregate types concrete mix ratio was executed according to ACI mix design method in order to produce C-25 concrete. The BMS and BCS concrete mixes have very close values with reasonable quantities of fine and coarse aggregates to shown better strength and good workability. The 1:2.84:3.85 mix ratio(1 hand cement,2.84 fine aggregate and 3.85 of blended coarse aggregates of 25% marble and 75% basalt) were meet the larger and optimum strength requirement from all mixes and the BCS mix ratio shown the second good strength by 1:2.84:3.86 mix ratio(while ceramic tile occupied 25% replacement for blended coarse aggregate)
4. In the workability test result all mixes except MCS(75% waste marble and 25% waste ceramic tile sample), they were in limits from 50-175mm which allows good workability but the MCS shown 17mm which was very low while the limit is between 0-25mm.
5. In both compressive and flexural tests of 28 days of curing the mix from partial replacement of waste marble tile about 25% with the 75% control coarse aggregate basaltic stone had shown the relatively high results from all concrete mixes in experimental specimens. And secondly the concrete mix from partial

replacement of ceramics tile with a control basaltic coarse aggregate had shown the larger from the control 100% basaltic coarse aggregate mix in both compressive and flexural strength and from the specified characteristics strength and mean target strength of C-25 concrete. Thus mixing the normal basaltic stone coarse aggregate with the marble tile or either using the ceramic tile wastes as second alternative from a waste that produced of buildings can enhances the development of concrete and at a time it reduces environmental pollutions from such waste types. And all concrete mixes are not beyond the limit that sets to assess the concrete production criteria and the expected strength requirement.

6. Light weight concretes are a results from their own types of ingredient selection criteria with the described properties and the mix design criteria, in this research C=MS; 50% waste ceramic and 50% waste marble tile specimen shows the lowest unit weight relatively from all concrete mixes by resulting 2333.45kg/m3 with a normal mix design criteria of C-25 concrete.In light weight, the savings arise not only from reduced footings, columns and beamsizes, but also from the enhanced thermal properties of the concrete.

6.2 Recommendation

The materials that used to replace the coarse aggregate were a wastes from building during its construction proceed and gained as a trash in the compound of JIT staff condominium and JIT, Jimma University compound, while experiments were apprehended, however, using this wastes as a coarse aggregate has a significant benefit for the concrete production in strength,density, workability, environmental manner even if the waste is low in amount.

The partial replacements of BMS mix recorded the better compressive and flexural strength rather than the control mix, thus using this marble tile coarse aggregate in partial substitution up to 25% will enhance the strength of structures and components in construction and at the same time reduce the waste from the environment even if they are not toxic but still they are wastes which harm environments indirectly and which can be find easily.

All concrete including the normal 100% crushed basaltic stone coarse aggregate mix and excluding the MCS mix have been shown medium level of slump which can be said vital for workability but MCS has the low workability slump level, thus the mixes are good in suitability in workability manner for the construction. The using of marble and ceramic tile coarse aggregates for construction with a partial replacement do not alter the workability and the required target mean strength thus, this experiment recommend the using of alternative coarse aggregates for partial replacement of basaltic stone with 25% of marble or ceramics respectively with strength manner for better strength and suitable for mixes of normal concrete.

For consultant/designers in order to provide C-25 concrete better strength, while they are finding alternative coarse aggregates to blend and make a concrete mixes, usingceramic and marble tile wastes for better structural loading capacity with 25% partial replacement is very preferable, and this experimental research recommend the C-25 concrete mix design in consultants by partial substitution of these wastes is helpful with enhanced strength, good workability and minimizing the waste from the environment.

For contractors, the disposal of these wastes after the projects are phased-out should be helpful while it is in proper manner for future use in concrete mix. Thus collecting this wastes from the completed and ongoing constructions with care and using them for coming projects will give a positive output for the concrete mixes.

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APPENDIX 1

MATERIALS TEST RESULTS

1.1 Properties of cement

The cement that used for all concrete mix was dangoteopc cement grade …

1.1.1 Fineness of Hydraulic Cement

Calculation of the fineness of the test sample as:

$$F = 100 - \left[\frac{R_s * 100}{W}\right] \text{.........................Equ.1A}$$

Where:

F= fineness of cement expressed as the percentage passing the sieve,

Rs = residue from sample retained on the sieve,

W = weight of sample in gram

Laboratory results

W=100gm   Rs=5gm

F=100-$\left[\frac{\mathrm{Rs}*100}{W}\right]$=100 − $\left[\frac{5.6*100}{100}\right]$ =**<u>94.4%</u> passing** or 100%-94.4=**<u>5.6%</u>** retaining ,then it is accepted According to Ethiopian Standard while, the weight of residue left on the sieve should be less or equal to **10%** of the total cement in treatment for ordinary Portland cement.

1.2. Properties of Fine Aggregate

1.2.1. Silt/clay content

Worabe,river sand was used for the sample of research test

Formula; silt content % (A) =$\left[\frac{B-C}{B}\right]$***100……………………………………Equ.2A**

Where: A= percentage of material that is finer than 75μm (#200) sieve size (percentage of silt/clay content)

B= Original dry mass before wash in gram,C= Dry mass of sample after washed in gram

Laboratory result

B=1000gm C=955gm

(A) =$\left[\frac{1000-955}{1000}\right]$*100= **4.5%**it is acceptable according to

1.2.2 Sieve Analysis of Fine Aggregate

Sieve analysis trial 1

Table 1A:Sieve Analysis of Fine Aggregate Trial 1.

Sieve size		Weight retained	Percent retained	Cumulative % retained	Percent passing	ASTM LIMITS	BS LIMIT
ACI sieve Size	Equiv.BS sieve						
9.5	3/8 in	0	0	0	100	100	100
4.75	3/16 in	0.195	9.75	9.75	90.25	95-100	89-100
2.3	#7	0.275	13.75	23.5	76.5	80-100	60-100
1.18	#14	0.35	17.5	41	59	50-85	30-100
0.6	#25	0.32	16	57	43	25-60	15-100
0.3	#52	0.28	14	71	29	10-30	5-70
0.15	#100	0.41	20.5	91.5	8.5	2-10	0-15
0.075	#200	0.14	7	98.5	1. 5	0-5	
Pan	….	0.03	1.5	100			
				293.5			

Fineness Modulus (FM) for the sand sample trial 1

Fineness modules (FM)=$\frac{\sum(cum\ of\ \%\ retained)}{100} = \frac{293.5}{100} = 2.935$

Sieve analysis trial 2

Table 1B:Sieve Analysis of Fine Aggregate Trial 2.

Sieve size		Weight retained	Percent retained	Cumulative % retained	Percent passing	ASTM LIMITS	BS LIMIT
ACI sieve Size	Equiv.BS sieve						
9.5	3/8 in	0	0	0	100	100	100
4.75	3/16 in	0.177	8.85	8.85	91.15	95-100	89-100
2.3	#7	0.279	13.95	22.8	77.2	80-100	60-100
1.18	#14	0.284	14.2	37	63	50-85	30-100
0.6	#25	0.44	22	59	41	25-60	15-100
0.3	#52	0.34	17	76	24	10-30	5-70
0.15	#100	0.33	16.5	92.5	7.5	2-10	0-15
0.075	#200	0.131	6.55	99.05	1. 5	0-5	
Pan	….	0.019	1.5	100			
				296.15			

Fineness modules (FM) For sand sample trial 2=$\frac{\sum(cum\ of\ \%\ retained)}{100} = \frac{296.15}{100} = 2.96$

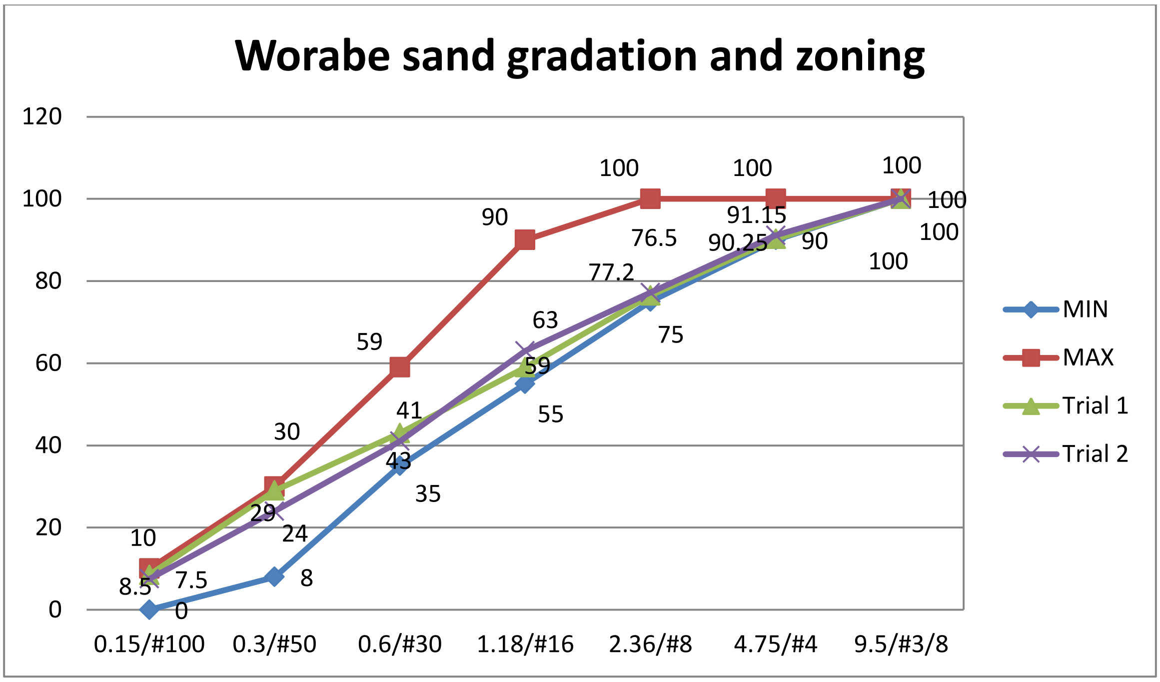

Figure 1A: Fine aggregate gradation chart

1.2.3. Unit weight

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

The sample was taken as two trials for both loose and compacted

Formula:for unit weight =

$$\frac{(\boldsymbol{weight\ of\ cylinder+weight\ of\ sample})-(\boldsymbol{weight\ of\ cylinder})}{\boldsymbol{volume\ of\ cylinder}}\text{..........................}\textbf{Equ.3A}$$

Table 1C:Compacted and Loose unit weight of worabe sand sample.

Compacted unit weight of worabe sand							
Sample	**weight of cylinder (kg)**	**weight of cylinder(kg)+weight of sample(kg)**	**Height of cylinder (m)**	**Diameter of cylinder(m)**	**weight of sample (kg)**	**Volume of cylinder(m^3)**	**Unit weight (kg/ m^3)**
Sample 1	4.0632	8.78	0.155	0.155	4.7168	0.002925	1612.6
Sample 2	4.0632	8.7567	0.155	0.155	4.6935	0.002925	1604.61
						Average	1608.6

Loose unit weight of worabe sand							
Sample 1	4.0632	8.4557	0.155	0.155	4.3925	0.002925	1501.7
Sample 2	4.0632	8.4861	0.155	0.155	4.4229	0.002925	1512.1
						Average	1506.9

1.2.4 Specific gravity, Water absorption and Moisture content of Fine aggregate

I) Specific Gravity (Saturated – surface – basis):

Specific Gravity formula (SSD) = $\frac{D}{B+D-C}$**…………………………………Equ.4A**

Where:

A= oven dry mass=494.6mg

B =mass penometer= 1.555kg

C=mass sample +penometer+water=1.860kg

D= mass sample=500mg

Specific gravity = $\frac{500}{1.555+500-1.865}$= **2.56**

II)Absorptioncapacity of fine Aggregate

The absorption capacity is measure of the porosity of an aggregate.

Absorption of course Aggregate capacity (%) = $\left(\frac{500-A}{A}\right)*100$ **…………Equ.5A**

Where: 500=Mass sample

A= oven dry mass=494.6mg

Absorption capacity (%) = $\left(\frac{500-494.6}{494.6}\right)*100$

Absorption capacity (%) =**1.09%**

III)Moisture content for Fine Aggregate

Formula; MC=$\left(\frac{\text{weight of orginal sample}-\text{weight of oven dry sample}}{\text{weight of oven dry sample}}\right)*100$**……..Equ.6A**

Weight of orginal sample= 500mg

Weight of oven dry sample= 493mg

W (%) = $\left(\frac{500\text{mg}-493\text{mg}}{493\text{mg}}\right)*100$ = **1.42%**

1.3 Properties of Coarse aggregates sample

1.3.1 Sieve Analysis of coarse aggregate

I) Crushed Basaltic stone coarse aggregate sieve analysis

Table 1D:Sieve analysis test results of crushed basaltic stone coarse aggregate.

Sieve size	Weight retained	Percent retained	Cumulative % retained	Percent passing	ASTM LIMITS	Remark
ACI sieve Size						
37.5	0	0	0	100	100	Ok
25	0.42	4.2	4.2	95.8	95-100	Ok
19	2.46	24.6	28.8	71.2	--	
12.5	4.3	43	71.8	28.2	25-60	Ok
9.5	2.05	20.5	92.3	7.7	--	
4.75	0.5	5	97.3	2.7	0-10	Ok
2.38	0.27	2.7	100	--	0-5	Ok
1.18	--	--	100	-	-	
0.6	--	--	100			
0.3	--	--	100			
0.015	--	--	100			
			718.5			

Fineness Modulus (FM) for the basaltic coarse aggregate sample

Fineness modules (FM)=$\frac{\Sigma(cum\ of\ \%\ retained)}{100} = \frac{718.5}{100} = 7.185$

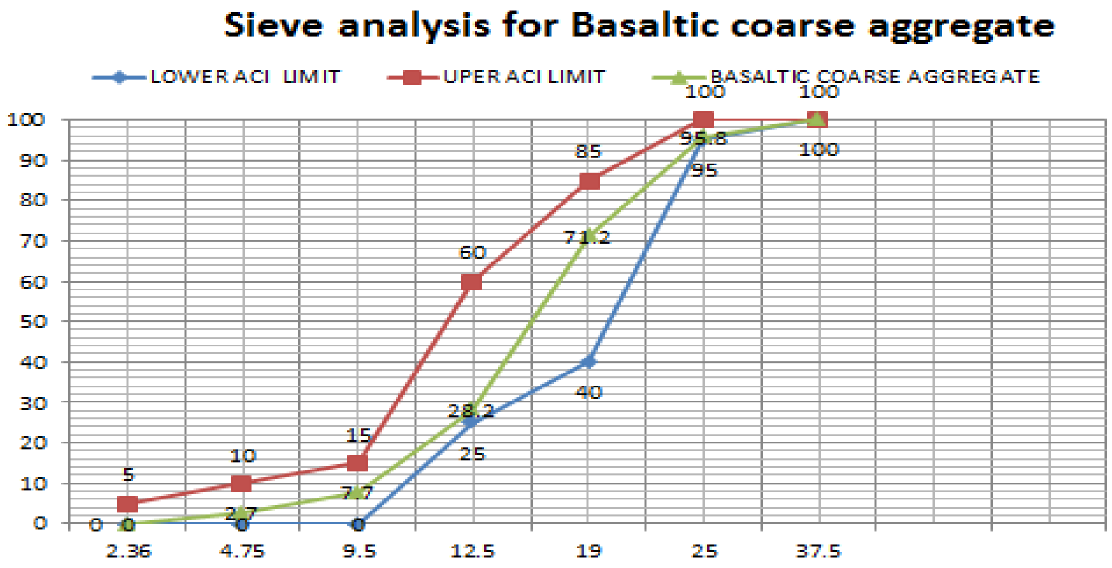

Figure 1B: Crushed Basaltic stone coarse aggregate gradation chart

II) white paste waste ceramics tile coarse aggregate sieve analysis

Table 1E:Sieve analysis test results of waste ceramic tile coarse aggregate.

Sieve size	Weight retained	Percent retained	Cumulative % retained	Percent passing	ASTM LIMITS	Remark
ACI sieve Size						
37.5	0	0	0	100	100	Ok
25	0.15	1.5	1.5	98.5	95-100	Ok
19	1.35	13.5	15	85	--	
12.5	5.12	51.2	66.2	33.8	25-60	Ok
9.5	2.3	23	89.2	10.8	--	
4.75	0.93	9.3	98.5	1.5	0-10	Ok
2.38	0.15	1.5	100	--	0-5	Ok
1.18	--	--	100	-	-	
0.6	--	--	100			
0.3	--	--	100			
0.015	--	--	100			
			702.7			

Fineness Modulus (FM) for waste white paste ceramics tile coarse aggregate sample

Fineness modules (FM)=$\frac{\sum(cum\ of\ \%\ retained)}{100} = \frac{702.7}{100} = 7.027$

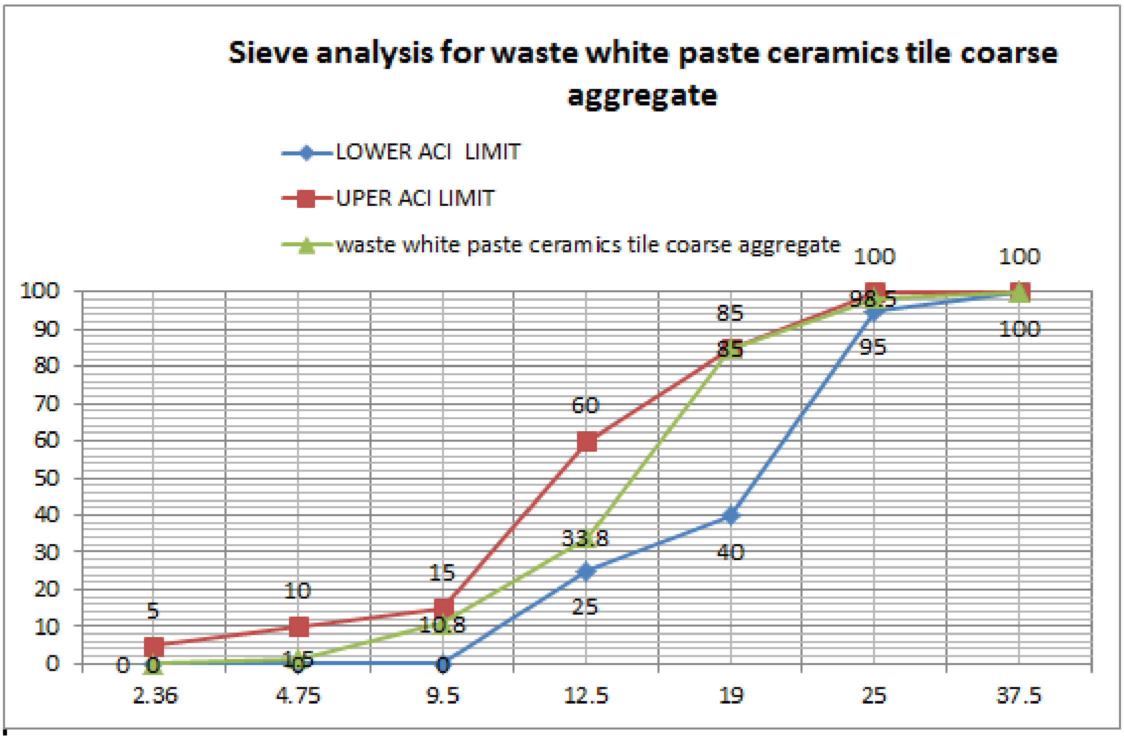

Figure 1C: Waste ceramics tile coarse aggregate gradation chart.

III)Waste white colored marble coarse aggregate sieve analysis

Table 1F:Sieve analysis test results of waste marble tile coarse aggregate.

Sieve size ACI sieve Size	Weight retained	Percent retained	Cumulative % retained	Percent passing	ASTM LIMITS	Remark
37.5	0	0	0	100	100	Ok
25	0.453	4.53	4.53	95.47	95-100	Ok
19	3.7	37	41.53	58.47	--	
12.5	3.1	31	72.53	27.47	25-60	Ok
9.5	1.821	18.21	90.74	9.26	--	
4.75	0.811	8.11	98.85	1.10	0-10	Ok
2.38	0.11	1.1	99.95	--	0-5	Ok
1.18	--	--	100	-	-	
0.6	--	--	100			
0.3	--	--	100			
0.015	--	--	100			
			731.07			

Fineness Modulus (FM) for the basaltic coarse aggregate sample

Fineness modules (FM)=$\frac{\sum(cum\ of\ \%\ retained)}{100} = \frac{731.07}{100} = 7.3107$

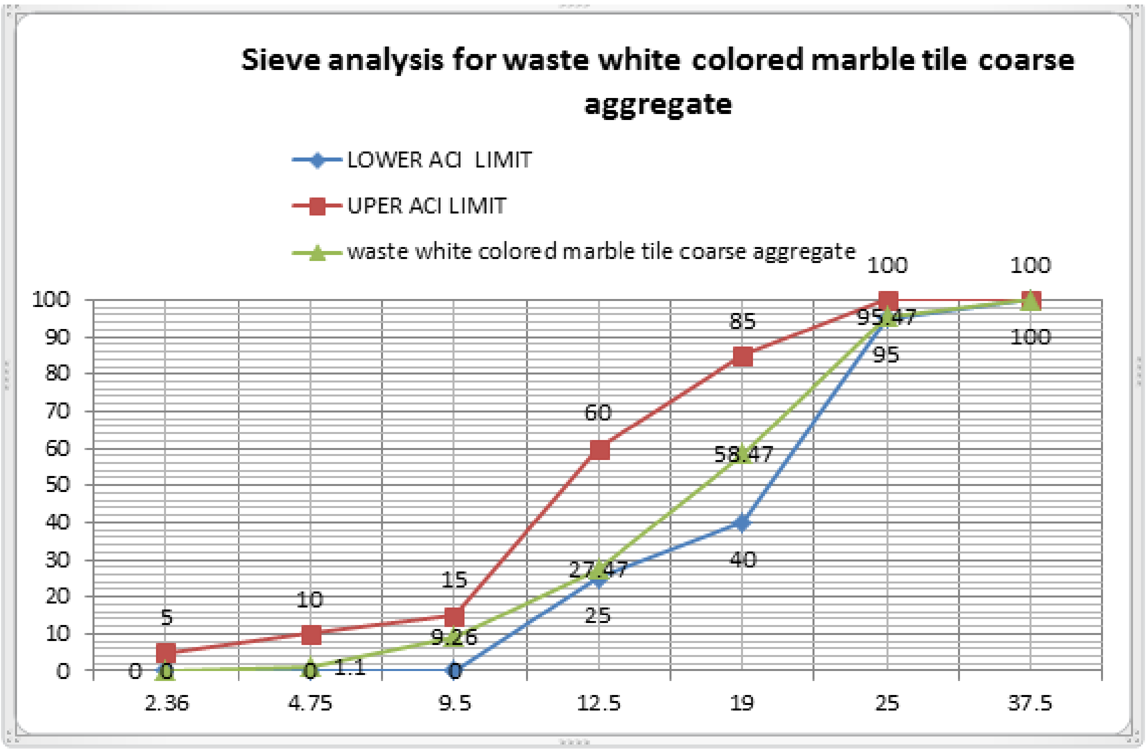

Figure 1D:Waste marble tilecoarse aggregate gradation chart

Sieve analysis for blended aggregates of waste ceramics and marble tiles coarse aggregate was essential for the ACI C-136 aggregates for concrete mix design parameter, thus in the following table the sieve analysis for the above described coarse aggregate was executed.

Table 1G:Sieve analysis test results of blended waste ceramic and marble tile coarse aggregates.

Sieve analysis for blended aggregates of waste ceramics and marble tiles coarse aggregate					
Sieve size	Aggregate 1 Passing %(ceramic)	Aggregate 2 Passing %(marble)	% passing Cumulative	% retained= 100%-%passing	Individual % retained combined aggregate
37.5	50	50	100%	0	0
25	49.25	47.73	96.98	3.02	3.02
19	42.5	29.235	71.735	28.265	25.245
12.5	16.9	13.735	30.635	69.365	41.1
9.5	5.4	4.63	10.03	89.97	20.605
4.75	0.75	0.55	1.3	98.7	8.73
2.36	0	0	0	100	1.3
1.18	0	0	0	100	-
0.06	0	0	0	100	-
0.03	0	0	0	100	-
0.015	0	0	0	100	-
0.0075				-	-
				716.935	

1.3.2 Unit weight of coarse aggregates

Cylinder (Mold) Mass= Internal Diameter =

Internal Height of cylinder = Volume of the Mold=

The sample was taken as two trials for both loose and compacted

Formula:for unit weight = $\frac{(weight\ of\ cylinder+weight\ of\ sample)-(weight\ of\ cylinder\ )}{volume\ of\ cylinder}$

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

Table 1H:Compacted and Loose unit weight of different types of coarse aggregate sample

Compacted unit weight of natural basalticcoarse aggregate							
Sample	weight of cylinder (kg)	weight of cylinder(kg)+weight of sample(kg)	Height of cylinder (m)	Diameter of cylinder (m)	weight of sample (kg)	Volume of cylinder (m^3)	Unit weight (kg/ m^3)
Sample 1	1.69kg	18.23			16.54	0.01m3	1654
Sample 2	1.69kg	17.76			16.07	0.01m3	1607
						Average	**1630.5**
Loose unit weight ofnatural basalticcoarse aggregate							
Sample 1	1.69kg				15.13	0.01m3	1513
Sample 2	1.69kg				15.22	0.01m3	1522
						Average	**1517.5**
Compacted unit weight of waste ceramics white paste tilescoarse aggregate							
Sample 1	1.69kg	16.8966			15.2066	0.01m3	1520.66
Sample 2	1.69kg	17.0656			15.3756	0.01m3	1537.56
						Average	**1530.11**
Loose unit weight of waste ceramics white paste tilescoarse aggregate							
Sample 1	1.69kg	15.7678			14.0778	0.01m3	1407.8
Sample 2	1.69kg	15.9426			14.2526	0.01m3	1425.26
						Average	**1416.53**
Compacted unit weight of waste white colored marblecoarse aggregate							
Sample 1	1.69kg	16.905			15.215	0.01m3	1521.5
Sample 2	1.69kg	16.88			15.1702	0.01m3	1517.02
						Average	**1500**
Loose unit weight of waste white colored marblecoarse aggregate							
Sample 1	1.69kg	15.992			14.302	0.01m3	1430
Sample 2	1.69kg	16.27			14.580	0.01m3	1458
						Average	**1444**

1.3.3 Specific gravity, water absorption and moisture content of different Coarse aggregates

I) Basaltic coarse aggregate

Weight of Aggregate in gm	Where:
A = 1998	A = weight of oven-dry sample in air, [g]
B = 2033.9	B = weight of saturated – surface – dry sample in air, [g] and
C = 1289.5	C = weight of saturated sample in water, [g]

A.Bulk Specific Gravity (Saturated – surface – basis):

Bulk Specific Gravity (SSD)= $\left[\frac{B}{B-C}\right]$

Bulk Specific Gravity (SSD)= $\left[\frac{2033.9}{2033.9-1289.5}\right]$=**2.73**

B.Absorption of course Aggregate capacity

The absorption capacity is measure of the porosity of an aggregate.

Water Absorption of course Aggregate capacity (%) = $\left[\frac{B-A}{A}\right]*100$

Absorption capacity (%) = $\left[\frac{2033.9-1999}{1999}\right]$*100=**1.74%**

Absorption capacity (%) = = **1.74%**

C.Moisture content of `Basaltic coarse aggregate

Weigh the sample of 2kg coarse aggregate and 500 gm fine aggregate record (A), the sample dry in oven and cool and weigh (B) and the calculate the moisture content.

W (%) == $\left[\frac{A-B}{B}\right]*100$=

WHERE; A is original sample of basaltic crushed stone stone ,2kg

B= 1.96 kg dry sample in oven

W (%) = =$\left[\frac{2-1.96}{1.96}\right]*100$=**2.04%**

II)White paste waste ceramic tile coarse aggregate

Weight of Aggregate in gm	Where:
A = 1999.56	A = weight of oven-dry sample in air, [g]
B = 2018.35	B = weight of saturated – surface – dry sample in air, [g] and
C = 1231.5	C = weight of saturated sample in water, [g]

A.Bulk Specific Gravity (Saturated – surface – basis):

Bulk Specific Gravity (SSD)=$\left[\frac{B}{B-C}\right]$

Bulk Specific Gravity (SSD)=$\left[\frac{2018.35}{2018.35-1231.5}\right]$=**2.565**

B.Absorption of course Aggregate capacity

The absorption capacity is measure of the porosity of an aggregate.

Water Absorption of course Aggregate capacity (%) = $\left[\frac{B-A}{A}\right]*100$

Absorption capacity (%) = $\left[\frac{2018.35-1999.56}{1999.56}\right]$*100=**0.94%**

Absorption capacity (%) = = **0.94%**

C. Moisture content of `white paste waste ceramics tile coarse aggregate

Weigh the sample of 2kg coarse aggregate and 500 gm fine aggregate record (A), the sample dry in oven and cool and weigh (B) and the calculate the moisture content.

W (%) == $\left[\frac{A-B}{B}\right]*100$=

WHERE; A is original sample of basaltic crushed stone stone ,2kg

B= 1.98 kg dry sample in oven

W (%) =$\left[\frac{2-1.96}{1.96}\right]*100$=**2.04%**

III)White colored waste marble tile coarse aggregate

Weight of Aggregate in gm	Where:
A = 1993.7	A = weight of oven-dry sample in air, [g]
B = 2017.9	B = weight of saturated – surface – dry sample in air, [g] and
C = 1271.5	C = weight of saturated sample in water, [g]

A.Bulk Specific Gravity (Saturated – surface – basis):

Bulk Specific Gravity (SSD)=$\left[\frac{B}{B-C}\right]$

Bulk Specific Gravity (SSD)=$\left[\frac{2017.9}{2017.9-1271.5}\right]$=**2.703**

B.Absorption of course Aggregate capacity

The absorption capacity is measure of the porosity of an aggregate.

Water Absorption of course Aggregate capacity (%) = $\left[\frac{B-A}{A}\right]*100$

Absorption capacity (%) = $\left[\frac{2017.9-1998.9}{1998.9}\right]$*100=**0.95%**

Absorption capacity (%) = = **0.95%**

C.Moisture content of `White colored waste marble tile coarse aggregate

Weigh the sample of 2kg coarse aggregate and 500 gm fine aggregate record (A), the sample dry in oven and cool and weigh (B) and the calculate the moisture content.

W (%) == $\left[\frac{A-B}{B}\right]*100$

WHERE; A is original sample of basaltic crushed stone stone ,2kg

B= 1.99 kg dry sample in oven

W (%) =$\left[\frac{2-1.97}{1.97}\right]*100$=**1.52%**

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APPENDIX 2

ACI -MIX DESIGN AND PROPORTION OF INGREDIENTS

1. The choice of slump was selected accordingly with the table of ACI: and the maximum slump preferred to mix design was75mm.

Table 2A: Recommended slumps for various types of construction

Types of construction	Slump, mm	
	Maximum*	Minimum
Reinforced foundation walls and footings	75	25
Plain footings, caissons, and substructure walls	75	25
Beams and reinforced walls	100	25
Building columns	100	25
Pavements and slabs	75	25
Mass concrete	75	25

2.The maximum size of coarse aggregate was selected by mechanisms of sieve analysis for different types of aggregates; namely normal varnero crusher basaltic crushed stone ,waste white paste ceramic tile coarse aggregate and waste white colored marble tile coarse aggregate and the sieve analysis shows the maximum size of coarse aggregate s for all three kinds of coarse aggregate was **37.5** sieve of ACI.

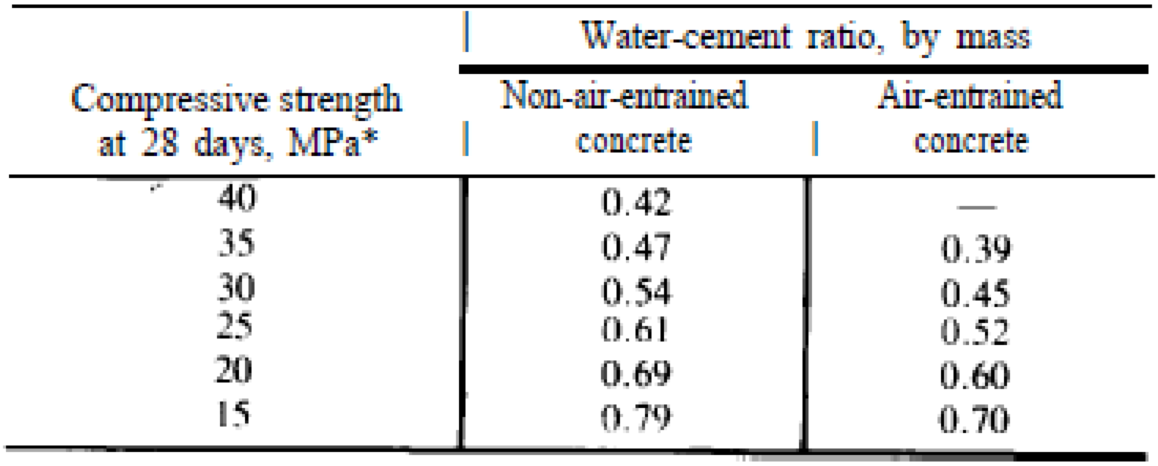
3. The concrete mix design was considered as non-air entrained since the structure is not exposed to severe weathering in Estimation of mixing water and air content by ACI method. And from the table below the appropriate mixing water and air was found by referring the slump, maximum size of aggregate and air entrained situation;**181kg/m^3** of mixing water was required.

Table 2B: Recommended slumps for various types of construction

	Water, Kg/m³ of concrete for indicated nominal maximum sizes of aggregate							
Slump, mm	9.5*	12.5*	19*	25*	37.5*	50†*	75†‡	150†‡
	Non-air-entrained concrete							
25 to 50	207	199	190	179	166	154	130	113
75 to 100	228	216	205	193	181	169	145	124
150 to 175	243	228	216	202	190	178	160	—
Approximate amount of entrapped air in non-air-entrained concrete, percent	3	2.5	2	1.5	1	0.5	0.3	0.2
	Air-entrained concrete							
25 to 50	181	175	168	160	150	142	122	107
75 to 100	202	193	184	175	165	157	133	119
150 to 175	216	205	197	184	174	166	154	—
Recommended average§total air content, percent for level of exposure:								
Mild exposure	4.5	4.0	3.5	3.0	2.5	2.0	1.5**††	1.0**††
Moderate exposure	6.0	5.5	5.0	4.5	4.5	4.0	3.5**††	3.0**††
Extreme exposure‡‡	7.5	7.0	6.0	6.0	5.5	5.0	4.5**††	4.0**††

4.Selection of water-cement or water-cementitious materials ratio is interrelated with the required compressive strength of concrete. From the table below the relationships between water-cement ratio and compressive strength of concrete, the water cement ratio was determined as**0.61** since the minimum compressive strength at 28 days was **25Mpa** at non air entrained manner.

Table 2C: **Relationships between water-cement ratio and compressive strength of concrete**



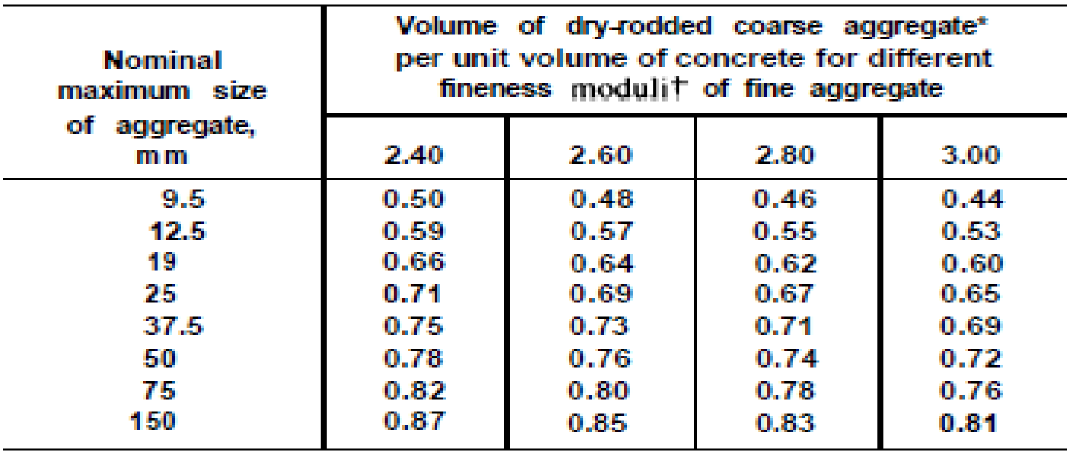
Compressive strength at 28 days, MPa*	Water-cement ratio, by mass	
	Non-air-entrained concrete	Air-entrained concrete
40	0.42	—
35	0.47	0.39
30	0.54	0.45
25	0.61	0.52
20	0.69	0.60
15	0.79	0.70

5. From the above information's the quantity of cement was calculated as :

$$\text{cement content} = \frac{\text{free water content}}{\text{water to cement ratio}} = \frac{181\text{kg/m3}}{0.62} = \boldsymbol{292kg/m3} \text{ of cement}$$

6.The quantity of coarse aggregate was estimated by referring a fineness modulus of fine aggregate and maximum size of coarse aggregate as **3** fineness modulus and **37.5 mm** maximum size of coarse aggregate , the table indicates that 0.69 m^3 of coarse aggregate, on a dry-rodded basis, may be used in each cubic meter of concrete.

Table 2D: Volume of coarse aggregate per unit volume of concrete with fine aggregate fineness modules



Nominal maximum size of aggregate, mm	Volume of dry-rodded coarse aggregate* per unit volume of concrete for different fineness moduli† of fine aggregate			
	2.40	2.60	2.80	3.00
9.5	0.50	0.48	0.46	0.44
12.5	0.59	0.57	0.55	0.53
19	0.66	0.64	0.62	0.60
25	0.71	0.69	0.67	0.65
37.5	0.75	0.73	0.71	0.69
50	0.78	0.76	0.74	0.72
75	0.82	0.80	0.78	0.76
150	0.87	0.85	0.83	0.81

For different types of coarse aggregate the dry -rodded mass of concrete was calculated independently to satisfy the desire of ACI mix design and the proportioning of concrete ingredients .

Basaltic stone coarse aggregate having 1630 kg /m3

The required dry mass is, therefore, 0.69m3 x 1630kg/m3 = ***1124.7 kg***.

Waste white paste ceramic tile coarse aggregate having 1530 kg /m3

The required dry mass is, therefore, 0.69m3 x 1530kg/m3 = ***1055.7 kg***.

Waste white colored marble tile coarse aggregate having 1524kg/m3

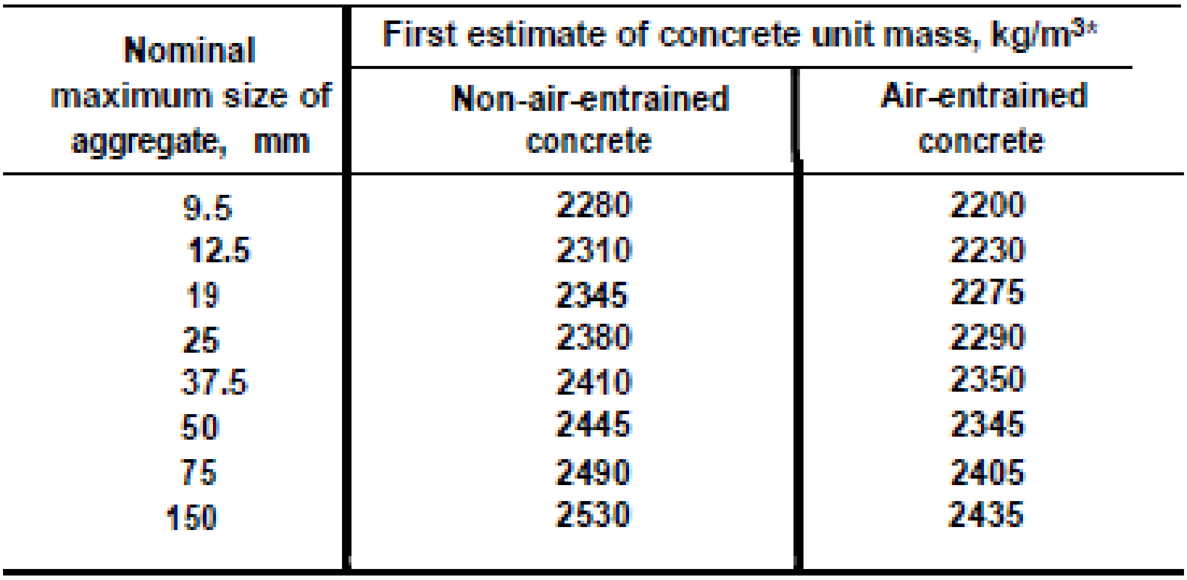
The required dry mass is, therefore, 0.69m3 x 1519kg/m3 = ***1048.11kg***.

7. The required fine aggregate content was determined in both basis of either mass or absolute volume as shown below:for different types of coarse aggregate;

Mass basis

From Table-5 below, the mass of a cubic meter of non-air-entrained concrete made with aggregate having a nominal maximum size of 37.5 mm is estimated to be ***2410 kg***. Masses already known are:

Table 2E: First estimate of weight of fresh concrete with nominal maximum size of coarse aggregate



Nominal maximum size of aggregate, mm	First estimate of concrete unit mass, kg/m^{3*} Non-air-entrained concrete	Air-entrained concrete
9.5	2280	2200
12.5	2310	2230
19	2345	2275
25	2380	2290
37.5	2410	2350
50	2445	2345
75	2490	2405
150	2530	2435

Mass basis :

For basaltic stone coarse aggregate: water (net mixing) =**181kg**, cement= **292kg**,coarse aggregate=***1124.7 kg***

For mass method the quantity of sand or fine aggregate =2410-(181+292+1124.7)=**812.3 kg of sand**

For Waste white paste ceramic tile coarse aggregate: water (net mixing) =**181kg**, cement= **292kg**,coarse aggregate =***1055.7 kg***

For mass method the quantity of sand or fine aggregate =2410-(181+292+1055.7)=**881.3 kgof sand**

For Waste white colored marble tile coarse aggregate: water (net mixing) =**181kg**, cement=**292kg**,coarse aggregate =***1048.11kg***

For mass method the quantity of sand or fine aggregate =2410-(181+292+1048.11)=**888.89 kg of sand**

Absolute Volume basis:

With the quantities of cement, water, and coarse aggregate established, and the approximate **entrapped air content** of **1 percent was considered in the above table;;;thus** the sand content was calculated as follows

For basaltic stone coarse aggregate:

$$\frac{W_w}{1000}+\frac{W_C}{1000SG_C}+\frac{W_{FA}}{1000SG_{FA}}+\frac{W_{CA}}{1000SG_{CA}}=1\ (m^3) \qquad \text{……………………….Equ.1B}$$

where:
W = Weight of water (Kg)
C = Weight of cement (Kg)
S = Weight of sand (Kg)
SG_C = Specific gravity of cement (3.15)
SG_{FA} = Specific gravity of sand

Volume of water = $\frac{181}{1000}$ 0.181 m^3

Solid volume of cement = $\frac{292}{3.15 \times 1000}$ 0.093 m^3

Solid volume of coarse aggregate=$\frac{1124.7}{2.73*1000}$=0.4119 m^3

Volume of entrapped air = 0.01 x 1.000 0.010 m^3

Then, solid volume of fine aggregate was =1m^3-(0.01+0.4119+0.093+0.181)=**0.3041m3**

Required weight of dry fine aggregate =0.3041=$\frac{x}{2.56*1000}$=778.496kg

For Waste white paste ceramic tile coarse aggregate:

Volume of water = $\frac{181}{1000}$ 0.181 m^3

Solid volume of cement = $\frac{292}{3.15 \times 1000}$ 0.093 m^3

Solid volume of coarse aggregate=$\frac{1055.7}{2.565*1000}$=0.4115 m^3

Volume of entrapped air = 0.01 x 1.000 0.010 m^3

Then solide volume of fine aggregate was =1m^3-(0.01+0.4115+0.093+0.181)=**0.3045m3**

Required weight of dry fine aggregate =0.3045=$\frac{x}{2.56*1000}$**=779.52kg**

For Waste white colored marble tile coarse aggregate:

Volume of water = $\frac{181}{1000}$ 0.181 m^3

Solid volume of cement = $\frac{292}{3.15 \times 1000}$ 0.093 m^3

Solid volume of coarse aggregate=$\frac{1048.11}{2.703*1000}$=0.3877 m^3

Volume of entrapped air = 0.01 x 1.000 $\underline{0.010\ m^3}$

Then , solid volume of fine aggregate was =1m^3-(0.01+0.3877 +0.093+0.181)=**0.3045m3**

Required weight of dry fine aggregate =0.3283=$\frac{x}{2.56*1000}$**=840.448kg**

Table 2F: Dry sand mass in mass and absolute volume method for different types of coarse aggregate for 1m3 concrete

Dry sand Mass in two basis		
Types of aggregate	**Mass basis**	**Absolute volume basis**
basaltic stone crushed coarse aggregate	**812.3**	**778.496**
Waste white paste ceramic tile coarse aggregate	**881.3**	**779.52kg**
Waste white colored marble tile coarse aggregate	**888.89**	**840.448kg**

7. Tests indicate total moisture of coarse aggregate and fine aggregate. Thus moisture adjustment were assumed for trial batch proportions based on assumed concrete mass were used,

For basaltic stone crushed coarse aggregate: moisture content was 2.04%, and for worabe sand moisture content was 1.42%

Coarse aggregate (Wet) =1124.7*(1+0.0204)=**1147.64388kg**

Fine aggregate (Wet) =812.3*(1+0.0142)= **823.83466kg**

Absorbed water does not become part of the mixing water and must be excluded from the adjustment in added water.

Moisture content-absorption for: Coarse aggregate=2.04%-1.74%=0.66%

:Fine aggregate=1.42%-1.09%=0.33%,

The estimated requirement for added water, therefore, becomes

181kg/m3-(1124.7*0.0066)-(812.3*0.0033)=**170.9kg**

For Waste white paste ceramic tile coarse aggregate: moisture content was 2.04%, and for worabe sand moisture content was 1.42%

Coarse aggregate (Wet) =1055.7*(1+0.0204)=**1077.23628 kg**

Fine aggregate (Wet) =**881.3***(1+0.0142)= **893.81446kg**

Absorbed water does not become part of the mixing water and must be excluded from the adjustment in added water.

Moisture content-absorption for: Coarse aggregate=2.04%-0.94%=1.1%

Moisture content-absorption for: :Fine aggregate=1.42%-1.09%=0.33%, The estimated requirement for added water, therefore, becomes

181kg/m3-(1055.7*0.011)-(**881.3***0.0033)= **166. 47kg**

For Waste white colored marble tile coarse aggregate: moisture content was 1.52%, and for worabe sand moisture content was 1.42%

Coarse aggregate (Wet) =1048.11kg *(1+0.0152)=**1064.041272 kg**

Fine aggregate (Wet) =**888.89***(1+0.0142) = **901.512238kg**

Absorbed water does not become part of the mixing water and must be excluded from the adjustment in added water.

Moisture content-absorption for: Coarse aggregate=1.52%-0.95%=1.1%

:Fine aggregate=1.42%-1.094%=0.33%, then The estimated requirement for added water, therefore, becomes

181kg/m3-(1048.11*0.0057)-(**888.89***0.0033)= **172.82kg**

8.The estimated batch masses for a cubic meter of concrete were:

Table 2G: Ingredient proportion for 1m3 concrete for different types of aggregate according to ASTM mix design

Dry Mass acoording to ACI mix design for different type of aggregate					
Types of aggregate	**Water(kg)**	**Cement**	**Fine aggregate**	**Coarse aggregate**	**Total**
basaltic stone crushed coarse aggregate	**170.9kg**	**292**	**812.3**	**1147.64388**	**2422.85**
Waste white paste ceramic tile coarse aggregate	**166. 47kg**	**292**	**881.3**	**1077.23628**	**2417**
Waste white colored marble tile coarse aggregate	**172.82**	**292**	**888.89**	**1064.041272**	**2417.8**

9. The calculated mixture proportions should be checked by means of trial batches prepared and tested in accordance with ASTM C 192.

For cylinder mold which volume is 0.003375m^3 (0.15m*0.15*0.15)m^3 three independent samples were prepared for the compressive tests of one concrete mix type for specific curing day, and 0.003375m^3*3=**0.010125m3**

And for flexural beam mold volume of 0.005m^3(0.1*0.1*0.5)m^3 also three independent samples were prepared for the flexural strength tests of one concrete mix type for specific curing day,and 0.005m^3*3= **0.015m3**

- Target mean strength for M25 mix design (Ft) is given by **Ft = Fck + k.S** , where**Fck** is characteristic compressive strength, **K** is constant and is taken as **1.65** and S is standard deviation.
  Therefore, Ft= 25 + 1.65*4.0 =**31.6MPa**.

APPENDIX 3

WORKABILITY, COMPRENSSIVE AND FLEXURAL STRENGH TEST RESULTS

3.1 Workability and Compressive Strength

Table 3A: Workability and Compressive Strength of Concrete at 28 days of curing

Control normal 100% Varnero crusher basaltic crushed stone coding "NBS''										
NO. of Sample	Test age days	Dimensions (cm)			W/C ratio	Average Slump (mm)	Weight (kg)	Failure load(kn)	Compressive strength(Mpa)	Unit weight
		L	W	H						
NBS1	28	15	15	15	0.61	71	8402.2	710.775	31.59	2489.55
NBS2		15	15	15	0.61		8426.6	766.5975	34.071	2495.78
NBS3		15	15	15	0.61		8475.8	741.825	32.97	2511.34
Average							8433.8	739.575	**32.87**	2498.89
50% waste white paste ceramic tiles and 50% waste white colored marble tile coarse aggregate coding "C=MS''										
C=MS1	28	15	15	15	0.61	94	7867.0	579.825	25.77	2330.98
C=MS2		15	15	15	0.61		7904.7	630.225	28.01	2342.15
C=MS3		15	15	15	0.61		7854.3	611.1	27.16	2327.22
Average							7875.2	607.05	**26.98**	2333.45
75% normal basaltic crushed stone aggregate and 25% waste white paste ceramic tile coarse aggregate Coding "BCS''										
BCS1	28	15	15	15	0.61	61	8203.6	730.575	32.47	2430.69
BCS2		15	15	15	0.61		8170.1	765.00	34.00	2420.77
BCS3		15	15	15	0.61		8181.7	739.8	32.88	2424.2
Average							8185.1	744.975	**33.11**	2425.22
75% normal basaltic crushed stone aggregate and 25% waste white colored marble tile coarse aggregate Coding "BMS''										
BMS1	28	15	15	15	0.61	77	8170.7	751.5	33.40	2420.96
BMS2		15	15	15	0.61		8143.5	810.45	36.02	2412.88
BMS3		15	15	15	0.61		8144.4	839.925	37.33	2413.14
Average							8152.9	802.8	**35.68**	2415.66
75% waste white paste ceramic tiles coarse aggregate and 25% waste white colored marble tile coarse aggregate Coding "CMS''										
CMS1	28	15	15	15	0.61	107	7966.9	585.495	26.022	2360.56
CMS2		15	15	15	0.61		7926.8	603.63	26.828	2348.69
CMS3		15	15	15	0.61		7937.5	549.675	24.43	2351.85
Average							7943.7	579.6	**25.76**	2353.7
75% waste white colored marble tile coarse aggregate and 25% waste white paste ceramics tile coarse aggregate Coding "MCS''										
MCS1	28	15	15	15	0.61	17	7957.3	660.15	29.34	2357.71
MCS2		15	15	15	0.61		8003.5	702.6075	31.227	2371.4
MCS3		15	15	15	0.61		7954.2	647.55	28.781	2356.9
Average							7971.7	670.05	**29.78**	2361.98

Table 3B: Workability and Compressive Strength of Concrete at 14 days of curing

Control normal 100% Varnero crusher basaltic crushed stone coding "NBS''										
NO. of Sample	Test age days	Dimensions (cm)			W/C ratio	Slump (mm)	Weight (kg)	Failure load(kn)	Compressive strength(Mpa)	Unit weight
		L	W	H						
NBS1	14	15	15	15	0.61	71	8426.7	679.725	30.21	2496.8
NBS2		15	15	15	0.61		8479.4	666.00	29.60	2512.4
NBS3		15	15	15	0.61		8409.7	616.95	27.42	2491.76
Average							8438.6	654.975	**29.11**	2500.32
50% waste white paste ceramic tiles and 50% waste white colored marble tile coarse aggregate coding "C=MS''										
C=MS1	14	15	15	15	0.61	94	7903	562.05	24.98	2341.62
C=MS2		15	15	15	0.61		7917.6	598.05	26.58	2345.96
C=MS3		15	15	15	0.61		7968.3	512.55	22.78	2360.98
Average							7929.6	557.55	**24.78**	2349.5
75% normal basaltic crushed stone aggregate and 25% waste white paste ceramic tile coarse aggregate Coding "BCS''										
BCS1	14	15	15	15	0.61	61	8159.7	685.80	30.48	2417.68
BCS2		15	15	15	0.61		8203.5	637.425	28.33	2430.66
BCS3		15	15	15	0.61		8226.4	632.3175	28.103	2437.46
Average							8196.5	651.9825	**28.977**	2428.6
75% normal basaltic crushed stone aggregate and 25% waste white colored marble tile coarse aggregate Coding "BMS''										
BMS1	14	15	15	15	0.61	77	8111.9	743.175	33.03	2403.52
BMS2		15	15	15	0.61		8133.7	732.15	32.54	2409.99
BMS3		15	15	15	0.61		8173.9	618.75	27.50	2421.89
Average							8139.8	699.075	**31.07**	2411.8
75% waste white paste ceramic tiles coarse aggregate and 25% waste white colored marble tile coarse aggregate Coding "CMS''										
CMS1	14	15	15	15	0.61	107	7904.2	571.725	25.41	2341.99
CMS2		15	15	15	0.61		7916.2	503.3025	22.369	2345.52
CMS3		15	15	15	0.61		7971.4	540.450	24.02	2361.89
Average							7930.6	538.4925	**23.933**	2349.8
75% waste white colored marble tile coarse aggregate and 25% waste white paste ceramics tile coarse aggregate Coding "MCS''										
MCS1	14	15	15	15	0.61	17	7978.9	588.15	26.14	2364.12
MCS2		15	15	15	0.61		7936.9	630.675	28.03	2351.69
MCS3		15	15	15	0.61		7977.9	646.4025	28.729	2363.83
Average							7964.6	621.7425	**27.633**	2359.88

Table 3C: Workability and Compressive Strength of Concrete at 7 days of curing

NO. of Sample	Test age days	Dimensions (cm)			W/C ratio	Slump (mm)	Weight (kg)	Failure load(kn)	Compressive strength	Unit weight (kg/m3)
		L	W	H						
Control normal 100% Varnero crusher basaltic crushed stone coding "NBS''										
NBS1	7	15	15	15	0.61	71	8396.5	554.175	24.63	2487.8
NBS2		15	15	15	0.61		8501.4	589.95	26.22	2518.9
NBS3		15	15	15	0.61		8438.9	628.65	27.94	2500.41
						Average	8445.6	590.91	**26.263**	2502.4
50% waste white paste ceramic tiles and 50% waste white colored marble tile coarse aggregate coding "C=MS''										
C=MS1	7	15	15	15	0.61	94	7891.6	476.775	21.19	2338.25
C=MS2		15	15	15	0.61		7913.2	547.425	24.33	2344.65
C=MS3		15	15	15	0.61		7789.3	534.825	23.77	2307.94
						Average	7864.7	519.66	**23.096**	2330.28
80% normal basaltic crushed stone aggregate and 20% waste white paste ceramic tile coarse aggregate Coding "BCS''										
BCS1	7	15	15	15	0.61	61	8188.5	600.975	26.71	2426.22
BCS2		15	15	15	0.61		8288.7	596.1375	26.495	2455.91
BCS3		15	15	15	0.61		8042.2	539.325	23.97	2382.87
						Average	8173.1	578.8125	**25.725**	2421.65
80% normal basaltic crushed stone aggregate and 20% waste white colored marble tile coarse aggregate Coding "BMS''										
BMS1	7	15	15	15	0.61	77	7908.3	592.425	26.33	2343.2
BMS2		15	15	15	0.61		8207.4	584.055	25.958	2431.82
BMS3		15	15	15	0.61		8211.3	607.7475	27.011	2432.977
						Average	8109	594.7425	**26.433**	2402.66
80% waste white paste ceramic tiles coarse aggregate and 20% waste white colored marble tile coarse aggregate Coding "CMS''										
CMS1	7	15	15	15	0.61	107	7984	520.65	23.14	2365.63
CMS2		15	15	15	0.61		7893	496.125	22.05	2338.66
CMS3		15	15	15	0.61		7945.8	503.775	22.39	2354.31
						Average	7941	506.835	**22.526**	2352.88
80% waste white colored marble tile coarse aggregate and 20% waste white paste ceramics tile coarse aggregate Coding "MCS''										
MCS1	7	15	15	15	0.61	17	7941.3	592.245	26.322	2352.97
MCS2		15	15	15	0.61		7917.2	572.85	25.46	2345.83
MCS3		15	15	15	0.61		8009.3	595.1475	26.451	2373.12
						Average	7955.2	586.7325	**26.077**	2357.1

3.2 Workability and Flexural Strength

Table3D: Workability and Flexural Strength of Concrete at 28 days of curing

NO. of Sample	Test age days	Dimensions (cm)			W/C ratio	Slump (mm)	Weight (kg)	Failure,crushingload(kn)	Flexural strength(Mpa)
		L	W	H					
NBS1	28	50	10	10	0.61	71		31.6824	5.16
NBS2		50	10	10	0.61			34.1384	5.56
NBS3		50	10	10	0.61			31.1912	5.08
Average							1249.4	32.2964	**5.26**
50% waste white paste ceramic tiles and 50% waste white colored marble tile coarse aggregate coding “C=MS’’									
C=MS1	28	50	10	10	0.61	94		26.50638	4.317
C=MS2		50	10	10	0.61			27.82034	4.531
C=MS3		50	10	10	0.61			25.2354	4.11
Average							10.7	26.5248	**4.32**
75% normal basaltic crushed stone aggregate and 25% waste white paste ceramic tile coarse aggregate									
BCS1	28	50	10	10	0.61	61		35.1822	5.73
BCS2		50	10	10	0.61			32.235	5.25
BCS3		50	10	10	0.61			34.384	5.601
Average							12.12	33.93578	**5.527**
75% normal basaltic crushed stone aggregate and 25% waste white colored marble tile coarse aggregate Coding “BMS’’									
BMS1	28	50	10	10	0.61	77		37.5154	6.11
BMS2		50	10	10	0.61			33.6472	5.48
BMS3		50	10	10	0.61			38.0066	6.19
Average							12.08	36.3488	**5.92**
75% waste white paste ceramic tiles coarse aggregate and 25% waste white colored marble tile coarse aggregate Coding “CMS’’									
CMS1	28	50	10	10	0.61	107		26.5862	4.33
CMS2		50	10	10	0.61			24.3758	3.97
CMS3		50	10	10	0.61			25.8494	4.21
Average							11.768	25.6038	**4.17**
75% waste white colored marble tile coarse aggregate and 25% waste white paste ceramics tile coarse aggregate Coding “MCS’’									
MCS1	28	50	10	10	0.61	17		31.8666	5.19
MCS2		50	10	10	0.61			29.0422	4.73
MCS3		50	10	10	0.61			30.8228	5.02
Average							11.809	30.5772	**4.98**

Table 3E: Workability and Flexural Strength of Concrete at 14 days of curing

Control normal 100% Varnero crusher basaltic crushed stone coding “NBS’’									
NO. of Sample	Test age days	Dimensions (cm)			W/C ratio	Slump (mm)	Weight (kg)	Failure load(kn)	Compressive strength(Mpa)
		L	W	H					
NBS1	14	50	10	10	0.61	71		29.9632	4.88
NBS2		50	10	10	0.61			32.6648	5.32
NBS3		50	10	10	0.61			27.1695	4.425
						Average	12.5	29.9325	**4.875**
50% waste white paste ceramic tiles and 50% waste white colored marble tile coarse aggregate coding “C=MS’’									
C=MS1	14	50	10	10	0.61	94		25.46872	4.148
C=MS2		50	10	10	0.61			24.69508	4.022
C=MS3		50	10	10	0.61		11.74	26.8318	4.37
						Average		25.6652	**4.18**
75% normal basaltic crushed stone aggregate and 25% waste white paste ceramic tile coarse aggregate Coding “BCS’’									
BCS1	14	50	10	10	0.61	61		30.2702	4.93
BCS2		50	10	10	0.61			29.7176	4.84
BCS3		50	10	10	0.61			27.8756	4.54
						Average	12.14	29.2878	**4.77**
75% normal basaltic crushed stone aggregate and 25% waste white colored marble tile coarse aggregate Coding “BMS’’									
BMS1	14	50	10	10	0.61	77		32.542	5.30
BMS2		50	10	10	0.61			30.4544	4.96
BMS3		50	10	10	0.61			32.6034	5.31
						Average	12.05	31.8666	**5.19**
75% waste white paste ceramic tiles coarse aggregate and 25% waste white colored marble tile coarse aggregate Coding “CMS’’									
CMS1	14	50	10	10	0.61	107		27.6914	4.51
CMS2		50	10	10	0.61			28.7966	3.69
CMS3		50	10	10	0.61			24.9898	4.07
						Average	11.75	25.1126	**4.09**
75% waste white colored marble tile coarse aggregate and 25% waste white paste ceramics tile coarse aggregate Coding “MCS’’									
MCS1	14	50	10	10	0.61	17		29.47814	4.801
MCS2		50	10	10	0.61			26.8011	4.365
MCS3		50	10	10	0.61			29.37376	4.784
						Average	11.78	28.551	**4.65**

Table 3F: Workability and Flexural Strength of Concrete at 7 days of curing

Control normal 100% Varnero crusher basaltic crushed stone coding "NBS''									
NO. of Sample	Test age days	Dimensions (cm)			W/C ratio	Slump (mm)	Weight (kg)	Failure load(kn)	Flexural strength (Mpa)
		L	W	H					
NBS1	7	50	10	10	0.61	71		26.4634	4.31
NBS2		50	10	10	0.61			26.5862	4.33
NBS3		50	10	10	0.61			24.4986	3.99
						Average	12.51	25.8494	**4.21**
50% waste white paste ceramic tiles and 50% waste white colored marble tile coarse aggregate coding "C=MS''									
C=MS1	7	50	10	10	0.61	94		22.5952	3.68
C=MS2		50	10	10	0.61			24.6214	4.01
C=MS3		50	10	10	0.61			24.0688	3.92
						Average	11.65	23.7618	**3.87**
80% normal basaltic crushed stone aggregate and 20% waste white paste ceramic tile coarse aggregate Coding "BCS''									
BCS1	7	50	10	10	0.61	61		25.9722	4.23
BCS2		50	10	10	0.61			26.4327	4.305
BCS3		50	10	10	0.61			24.3144	3.96
						Average	12.108	25.5731	**4.165**
80% normal basaltic crushed stone aggregate and 20% waste white colored marble tile coarse aggregate Coding "BMS''									
BMS1	7	50	10	10	0.61	77		25.8494	4.21
BMS2		50	10	10	0.61			25.3582	4.13
BMS3		50	10	10	0.61			27.9984	4.56
						Average	12.013	26.402	**4.30**
80% waste white paste ceramic tiles coarse aggregate and 20% waste white colored marble tile coarse aggregate Coding "CMS''									
CMS1	7	50	10	10	0.61	107		21.52684	3.506
CMS2		50	10	10	0.61			24.3758	3.97
CMS3		50	10	10	0.61			22.4724	3.66
						Average	11.76	22.79168	**3.712**
80% waste white colored marble tile coarse aggregate and 20% waste white paste ceramics tile coarse aggregate Coding "MCS''									
MCS1	7	50	10	10	0.61	17		22.6566	3.69
MCS2		50	10	10	0.61			26.8318	4.37
MCS3		50	10	10	0.61			26.402	4.3
						Average	11.78	25.2968	**4.12**