JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

FACULTY OF CIVIL AND ENVINROMENTAL ENGINEERING

STRUCTURAL ENGINEERING STREAM

EXPERIMENTAL AND ANALYTICAL STUDY ON PROPERTIES OF C-25 GRADE CONCRETE REPLACING COARSE AGGREGATE BY WASTE CERAMIC AND FINE AGGREGATE STONE DUST

A Thesis Submitted to School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Structural Engineering

BY:

DEREJE BEYISE ABDETA

July, 2021

JIMMA, ETHIOPIA

JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

FACULTY OF CIVIL AND ENVINROMENTAL ENGINEERING

STRUCTURAL ENGINEERING STREAM

EXPERIMENTAL AND ANALYTICAL STUDY ON PROPERTIES OF C-25 GRADE CONCRETE REPLACING COARSE AGGREGTATE BY WASTE CERAMIC AND FINE AGGREGATE BY STONE DUST

A Thesis Submitted to School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree Masters of Science in Structural Engineering

BY:

DEREJE BEYISE ABDETA

MAIN ADVISOR: DR. KABTAMU GETACHEW

CO- ADVISOR: ENGR. ASHAGERE FETENE (M.sc)

Ju1y, 2021

JIMMA, ETHIOPIA

DECLARATION

I Dereje Beyise Abdeta, here by do declare that all the work done in this study entitled **"**Experimental and analytical study on properties of C-25 grade concrete replacing coarse aggregate by ceramic waste and fine aggregate stone dust**"** originates from my own work and has not been presented by any other person for an award of a degree in Jimma Institute of Technology or other University. All secondary sources referred in this work have been duly acknowledged and cited.

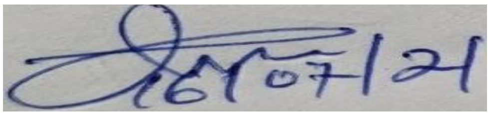
Name: Dereje Beyise Abdeta

Signature ______________________

Place: Jimma University

Jimma Institute of Technology

Date: Ju1y, 2021

Dr. Kabtamu Getachew (PHD)  ___________________

Advisor Signature Date

Eng. Ashagre Fetene (M.Sc.) ____________________ ___________________

Co-Advisor Signature Date

ABSTRACT

Concrete is the most widely used man made construction material in construction industries. It is mainly composed of cement, fine aggregate, coarse aggregate and water. The properties of concrete are mainly affected by its ingredient's types, quantity and quality. The cement is used to bind the materials in concrete. Fine aggregate and coarse aggregate will fill the most of the spaces in concrete. There are numerous materials that can replace each constituent in concrete. In this study grinded CW was used to partially replace coarse aggregate and SD is replaced fine aggregate at 0% ,$5\%\ CW - 25\%\ SD, 10\%CW - 50\%SD, 15\%\ CW - 75\%SD, and\ 20\%CW - 100\%\ SD$ *dosage by weight proportion to evaluate various strength parameters like compressive strength, split tensile strength and flexural strength. Concrete is strong in compression but it is weak in tension, brittle, low resistant to cracking, lower impact strength and heavy weight. CW and SD are one of the solid wastes in our surroundings which mostly pollute the environment condition. In order to overcome such types of problems related to pollution of environment the study deals the engineering property of concrete with CW and SD waste.*

Workability, compressive strength, split tensile strength and flexural strength test were performed to determine the competence of reusing CW and SD in the production of concrete. The average of three identical sample tests for each strength was used to determine the strength of concrete and tested at 7, 14, and 28 days of curing age. All cubes were made with $150mm \times 150mm \times 150mm$, *cylinders with 100mm diameter and 200 mm height and beams with cross-section* $100mm \times 100mm$ *and length of 500mm size.*

The study result revealed that the density increases for all percentage replacement, mechanical strength of concrete decreases with increasing dosage of CW and SD and workability decreases with the increase of CW and SD. The optimum dosage was found to be $10\%\ CW - 50\%\ SD$. *At optimum the compressive strength decreases up to* 2.93%, *tensile strength decreases by* 2.4% *and flexural strength decreases by* $3.67\%\ for\ 10\%\ CW - 50\%\ SD$ *replacement in the concrete mix when compared with control concrete. The analytical simulation is done by ABAQUS version 6.14.5 on flexural strength of beam to check the load control and modulus rupture to validate with experiment.*

***Keywords**: Ceramic waste, Compressive strength, Fine aggregate, Flexural strength, Stone dust, Tensile strength,*

ACKNOWLEDGEMENT

First of all, I would like to acknowledge my indebtedness and render my warmest thanks to my Advisor Dr. Kabtamu Getachew (PHD) who made this work possible. His friendly guidance and expert advice have been invaluable throughout all stages of the work.

I would also wish to express my gratitude to Eng.Ashagre Fetene (M.Sc.) for extended discussions and valuable suggestions which have contributed greatly to the improvement of the thesis.

My sincere gratitude also goes to laboratory technicians Mr. Teklu Amenu and Mr. Habtamu A. for providing me with necessary guidance and equipment to perform various tests in this thesis, and for the endurance during all the laboratory experiments.

Lastly, special thanks also go to my family. Without their support and encouragement, completing this work would have been all the more difficult

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

ACI ………………………American Concrete Institute

ASTM ……………………American Society of Testing Material

BS………………………… British standard

CDP ………………………Concrete Damage plasticity

CW………………………. Ceramic Waste

EBCS………………………Ethiopian Building Construction Code and Standards

FEA ……………………… Finite Element Analysis

FM ……………………… Fineness Modulus

JIT…………………………Jimma Institute of Technology

M00 ……………………… 0 % ceramic waste coarse and 0% stone dust fine aggregate

M25……………………… 5 % ceramic waste coarse and 25% stone dust fine aggregate

M50 ……………………… 10% ceramic waste coarse and 50% stone dust fine aggregate

M75 ……………………… 15% ceramic waste coarse and 75% stone dust fine aggregate

M100……………………… 20% ceramic waste coarse and 100% stone dust fine aggregate

MR ……………………… Modulus of Rupture

MSA………………………. Maximum size of aggregate

NHIW………………………Non-Hazardous Industrial Waste

PSD …………………………Particle Size Distribution

SD …………………………. Stone dust

SSC …………………………. Stress-Strain Curve

SSD ..……………………….. Saturated-surface dry condition

UTM ………………………... Universal Testing Machine

CHAPTER ONE

INTRODUCTION

1.1. Back ground of the Study

Concrete is one of the most widely used construction materials in the world, mainly due to its favorable features such as durability, versatility, satisfactory, compressive strength, cost effectiveness and availability. Concrete is the mixture of fine aggregate (sand), cement, water and admixtures. Concrete plays a vital role in the development of infrastructures like, building, bridges, highways, dam and industrial structures etc., leading to utilization of large quantity of concrete. So, the rapid increase in the price of conventional construction materials

Today concrete has the great advantages over the other alternative structural materials like lumber and steel due to the advancement of material science by applying this science to the production of concrete; durability and sustainability of concrete can be improved the in near future. Design Mix of concrete is an art by which we can prepare a concrete mix using optimum quantity of fine aggregates, coarse aggregates, water and cement. Nowadays, sustainability is an issue where we have to make things happened without harming the environment and reduction in the use of Natural Resources as much as possible [1].

Aggregates are the vital constituents of the concrete. In the extraction of aggregates from the river, it causes the river to cut its channel through the bottom of the valley floor in both upstream and downstream of the removal place. The sand mining in rivers had gone up to such an extent that in many countries, there is a legal prohibition on sand mining. Even In places where there is no debar, nowadays satisfactory sand is not promptly available which is required to transport sand over a long distance. The search for an alternate source is of high- priority. If an appropriate industrial or agricultural by-product, which is a waste material, is used to replace sand partially it will diminish the problems and complications due to the inadequacy of sand [2].

Production of concrete requires large quantity of natural resource. Additionally, various government agencies have put restrictions on natural resource to conserve this diminishing natural resource. Now day’s natural raw materials are very scarce and increased cost of natural aggregates forces researchers to find alternatives to both coarse and fine aggregate in concrete. In order to make concrete industry sustainable, the use of waste materials in place of natural resources is one of the best approaches. In this rapid industrialized world recycling of construction materials plays an important role. Recycled concrete aggregates may be obtained from industrial waste, construction and demolition waste.

The ceramic waste from ceramic industries is a major contribute to construction and demolition waste, representing a technical and economic problem of society nowadays. It has been estimated that about 30% of the daily production in the ceramic industry goes to waste. This waste is not recycled in any form at present. However, the ceramic waste is durable, hard and highly resistant to biological, chemical and physical degradation forces. As the ceramic waste is piling up every day, there is pressure on the ceramic industries to find a solution for this disposal [3]. Ceramic wastes are also produced as result of ceramic processing. These waste causes soil, air and groundwater pollution. The practice of dumping and /or the inadequate management of waste from the various manufacturing sectors have had a notable impact on the receiving environment, leading to water, soil, air, and noise pollution, amongst other complications, and adding to existing environmental problems. At the same time, these practices represent an economic cost. However, if waste is managed correctly, it can be converted into a resource which contributes to savings in raw materials, conservation of natural resources and climate, and promotes sustainable development [4].

Stone dust is a byproduct of the crushing process which contains particle size from 0.75 to 5 mm. These stone dusts are not usable and dumped for land filling. But for few past years it has been utilized more than dumping to the other works like making concrete blocks and landscaping. Many works have been carried out to explore the benefits of using various waste materials such as granite dust, marble dust, quarry dust, plastic waste and glass powder in making and enhancing the properties of concrete.

One such option is the use of stone dust a byproduct of stone quarry as replacement of fine aggregate and ceramic waste as a replacement of coarse aggregate. These materials are easily available at very low monetary value as compared to natural fine and coarse aggregates. So, in the present work, an effort has been constituted to evaluate the suitability of SD and CW in concrete making. In the laboratory stone dust will be as fine aggregate in place of sand and ceramic waste will be as a partial substitute to coarse aggregate in concrete.

1.2. Statement of the Problem

The current booming construction industries demand large reserves of construction materials and skilled workmanship. Having the luxury of abundant construction materials is one of the manifestations of a great construction industry. Constructions from concrete can no longer more strength and durability unless the aggregate for the structures have good characteristics that expected from stone properties. River sand and crushed stone are one the main construction materials. Rapid and constantly usage of river sand and crushed rock is become leading to environmental problems related with depletion. Different aggregate type finds in different as conventional concrete main constituent in a manner of waste materials [5].

Today's our country reach with an important consumption and a growing need for aggregates because of the increasing in industrial production and booming of constructions, this situation become to a fast depletion of natural resources. On the other hand, a large volume of other waste material such as stone dust from stone crusher and ceramic wastes from demolished constructions, completed buildings and industries wastes considered as they are useless and environmental pollutant. But there are many possible materials have good qualities to replace the aggregate. Many researchers found few aggregate the enhance the concrete quality regarding on their mechanical properties including hardened and fresh concrete, durability and lack of conventional aggregate and river sand, economic and environmental issue.

When we look at the current availability and condition of river sand and crushed stone rock in Ethiopia, one can easily see that it is alarming issue. So, river sand is most commonly used fine aggregate and crushed angular stone is used coarse aggregate in concrete but due to acute shortage in many areas, availability, cost and environmental impact are major concern. Additionally, the sources of rivers sand and crushed rock are located several hundred kilometers away from the capital where the majority of the construction industry is located. To overcome from this crisis, partial replacement of sand with stone dust and ceramic waste as coarse aggregate can be an economic alternative. The concept of using stone dust as fine aggregate and ceramic waste as coarse aggregate is will be highlight in this work, because the demand of river sand and crushed stone is very high. The need for reliable material with less cost replacement of sand and coarse aggregate high priority. These materials are easily available at very low monetary value as compared to natural fine and coarse aggregates. So, in the present work, an effort has been constituted to evaluate the suitability of stone dust and ceramic waste in concrete making. In the laboratory stone dust will be as fine aggregate in place of sand and ceramic waste will be as a partial substitute to conventional coarse aggregate in concrete.

1.3. Research questions

- ✓ What is the effect of partially replacing fine aggregate by stone dust (SD) and coarse aggregate by ceramic waste (CW) on the workability of fresh concrete?
- ✓ In partially replacing of fine aggregate by stone dust and coarse aggregate by ceramic waste what is the significant effect on the strength characteristics of concrete?
- ✓ What is the optimum percentage partial replacement of stone dust as fine aggregate and ceramic waste in concrete strength characteristics?
- ✓ What is the relationship of concrete stress and strain in the partial replacement of fine aggregate with stone dust and coarse aggregate with ceramic waste in concrete mix?

1.4. Objectives of the Study

1.4.1. General Objective

The main objective of the study will be experimental and analytical study on properties of C-25 grade concrete in which is partially replacing fine aggregate by stone dust and Coarse aggregate by ceramic waste.

1.4.2. Specific Objectives

1. To investigate the workability of replacing stone dust as fine aggregate and ceramic waste as coarse aggregate on fresh concrete
2. To evaluate the various strength parameters like compressive strength, flexural strength test and split tensile strength.
3. To determine the optimum percentage partial replacement of stone dust as fine aggregate and ceramic waste as coarse aggregate in concrete in terms of concrete workability and strength.
4. To find out the basic relationship of concrete stress and strain diagram after partial replacement.

1.5. Significances of the Study

The importance of this study deals with the effect of using partial replacement of SD as fine aggregate and CW as coarse aggregate in concrete mix which specifically for fresh concrete considers workability test, for hardened concrete compressive, flexural strength and split tensile strength. After laboratory test result, the determination and comparison of stress-strain in the concrete section based on partially replacing fine aggregate and coarse aggregate or not partially replacing fine aggregate with stone dust and coarse aggregate with ceramic waste will be considered.

The other importance is to benefits people in attaining its objective as a center of academic excellence and accelerates the national development through provision of problem-solving research output to the policy and decision makers.

1.6. Scope and Limitation of the study

In this study, stone dust and ceramic waste will be collected to replace fine aggregate and conventional coarse aggregate in concrete respectively. In order to complement the research and to gain a comprehensive perspective on the growing volume of research on sand and coarse aggregate modified concrete laboratory tests such as workability test, compressive strength, split tensile strength, flexural strength. Also effect of stone dust and coarse aggregate on the mechanical properties of concrete with and without partial replacement of fine aggregate with SD and coarse aggregate with CW will employed. Laboratory studies will be conducted to determine the suitability of the concrete with partial replacement of waste SD as fine aggregate and CW as coarse aggregate in the construction industry.

All beams, all cubes and all cylinders have similar geometry and the same water cement mix ratio. The total length of beam cross section of $100mm \times 100mm$ length 500mm, for cubes $150\ mm \times 150\ mm \times 150\ mm$ and a cylinder of $100\ mm \times 200\ mm$ for split tensile testes. In all concrete mix the row material will consist of: Pozzolana Portland cement (PPC) of Dangote 32.5 grade, sand and crushed coarse aggregate (CCA). At the end the experimental study on the flexural beam, failure load and modulus of rupture (stress) of the beam are simulated (validated) by commercial finite element package ABAQUS version 6.14.5.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

This chapter review with different literatures about partial replacement of ceramic waste and stone dust material in concrete production individually. This paper will focus on the combination of ceramic waste and stone dust material as partial replacement of coarse aggregate and fine aggregate respectively in the concrete production. Here are some literatures that are discussed on ceramic waste as partial replacement of natural coarse aggregate and stone dust as partial replacement of natural fine aggregate for concrete production.

2.1. Back grounds

Concrete is the world's most important construction material. The quality and performance of concrete plays a great role for most of the infrastructures including commercial, industrial, residential and military structures, dams, Power plants and transportation systems. Concrete is the single largest manufactured material in the world and accounts for more than 6 million metric tons of materials annually. The worldwide use of concrete materials accounts for nearly 780 billion dollars in annual spending [6].

We know that construction industry is a huge industry and still blooming rapidly all over the world. Even if its growth is so essential, its development also has a lot of disadvantages, especially from the environmental protection point of view. Construction industries have a larger part in contributing these environmental problems. The extensive resource depletion is occurred due to the usage of large volume of construction materials [7]. According to other research finding construction accounts for 24% of global raw materials removed from the earth [8]. Also, the extraction, processing, transport and installation of materials associated with construction consume large quantities of energy and water.

The valorization of waste in civil engineering is important sector to extent that the products to be obtained are not subjected to rigorous quality standards too. The valorization of waste affects two major impacts, environmental impact is solved by disposing of such waste and the economic impact is the use of that in industry or in the field of construction, this waste has the advantage of being available large quantity and low value. Recycling of such wastes as a sustainable construction material appears to be a viable solution not only for pollution problems control, but also as an economical option in the design of green building [3].

So, to overcome this problem that is the scarcity of natural aggregate for construction purpose and high accumulation of waste material that affect the environment we need to find solution. So that in this research will be study on partially replacement of stone dust as fine aggregate and ceramic waste as coarse aggregate.

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

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). Basalt, hard, tough, strong: -Excellent aggregates [9]. 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 [10].

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.

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 [9]. 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. 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 [11].

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 [9].

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 aggregate [9] Problems: Cost of crushing, grading, dust control, and separation of undesirable constituents.

2.2.2. Coarse Aggregate Properties and Standard

I. Density

a) **Apparent Specific Gravity:** Density of the material including the external pores.

b) **Specific Gravity**: The specific gravity (relative density) of an aggregate is the ratio of its weight to the weight of an equal volume of water. [9] Most natural aggregates have specific gravities between 2.4 and 3.0

$$SG = \frac{Density\ of\ solid}{Density\ of\ Water} \qquad Equ.1$$

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

c) **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. [12] Bulk Density affects the following concrete behavior: mix design, workability, and unit weight. The rodded bulk density of aggregates used for normal weight concrete generally ranges from 1200 to $1760\ Kg/m^3$ [13]

II. 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 $110\ \pm 5°C$ for sufficient time to remove all uncombined water [14].

$$Absorption, \% = \frac{WSSD - WOD}{WOD} \times 100 \qquad Equ. 2$$

2.2.3. Characteristics dependent on prior exposure and processing factors.

I.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. Using the largest possible maximum size will result in: a) Reduction of cement content b) Reduction in water requirement c) Reduction of drying shrinkage [15].

II.Aggregate Grading

The distribution of particles of granular materials among various sizes is determined in accordance with ASTM C-136, “Sieve 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 [13]. That portion of an aggregate passing the $4.75mm$ (No.4) sieve and predominantly retained on the $75\mu m$ (No.200) sieve is called “fine aggregate” and larger aggregate is called “coarse aggregate”[13]. Gradation plays an important role in the workability, segregation, and pump ability of the concrete.

A. **Coarse-Aggregate Grading**

The maximum size of coarse aggregate used in concrete has a bearing on the economy of concrete. Usually, more water and cement are required for small-size aggregates than for large sizes, due to an increase in total aggregate surface area. 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. 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. 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. Most specifications allow 10 to 30% to pass the 300 µm sieve, and 2 to 10% to pass the 150 µm sieve. ASTM C 33 permits the lower limits for percent passing the 300 and 150 µm sieves to be reduced to 5 and 0, respectively [13].

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 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. 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 [15].In BS 882:1992 considers four grading zones; the division into zones is based primarily on the percentage passing the 600µm sieve. 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. Table 2.1 shows the grading requirement of BS and ASTM for fine aggregate. BS 882 divides the grading in to four zones, zone 1 is coarser and zone 4 is finer. Grading zone 2 and 3 is moderate grading zones and approach to ASTM standard

Table 2. 1 BS and ASTM grading requirement for fine aggregate (Neville, 1999)

Sieve size		Percentage by weight passing sieves				
		BS 882:1992				ASTM standard C33-78
BS	ASTM No.	Grading Zone-1	Grading Zone-1	Grading Zone-1	Grading Zone-1	
9.5mm	3/4 in	100	100	100	100	100
4.75mm	3/16 in	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
600µm	30	15-34	35-59	60-79	80-100	25-60
300µm	50	5-20	8-30	12-40	15-50	10-30
150µm	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 course to fine aggregate ratio is given in Table 2.2 as follows (Neville, 1999).

Table 2. 2 ASTM standard sieve designation for both fine and coarse aggregates [13].

Standard sieve designation (ASTM E11)		Nominal sieve opening	
		mm	in.
Coarse Sieves			
Standard	Alternative		
75.0 mm	3 in	75	3
63.0 mm	2-1/2 in	63	2.5
50.0 mm	2 in	50	2
37.5 mm	1-1/2 in	37.5	1.5
25.0 mm	1in	25	1
19.0 mm	3/4 in	19	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	0.187
2.36mm	No.8	2.36	0.0937
1.18mm	No.16	1.18	0.0469
600µm	No.30	0.6	0.0234
300µm	No.50	0.3	0.0117
150µm	No.100	0.15	0.0059
75µm	No.200	0.075	0.0029

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

Table 2. 3 Common physical property range of concrete aggregates for mix design [13].

Property	**Typical ranges**
Fineness modulus of fine aggregate	2.0 – 3.3
Nominal maximum size of coarse aggregate	9.5 - 37.5mm
Absorption	0.5 - 4%
Bulk specific gravity (relative density)	2.3 -2.9
Dry rodded bulk density	1280 – 1920 kg/m^3
Surface moisture content coarse aggregate	0-2%
Surface moisture content fine aggregate	0-10%

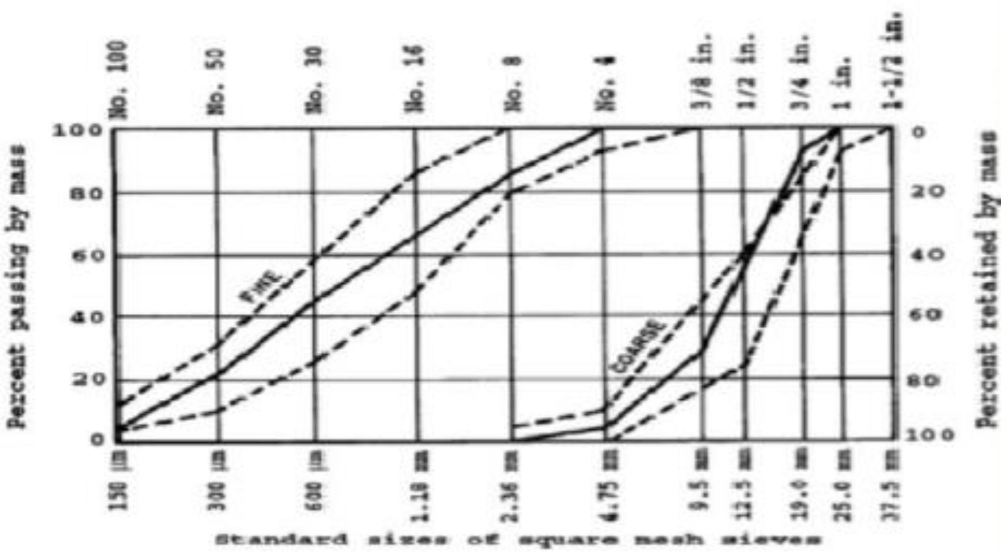


Figure 2- 1:Typical grading chart, specified in ASTM C 33 for fine and nominal coarse aggregate size 25 mm [13].

NB: Dashed lines shows the limit

III.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)].

$$Fineness\ Modulus = \frac{\sum cumulative\ retained}{100} \qquad Equ.3$$

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 coarser the aggregate, the higher the FM. For fine aggregate used in concrete, the FM generally ranges from 2.2 to 3. as called for in ASTM C 33, but in some cases, fine sands are used with an FM less than 2.0 [13].

- ✓ 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 [9].

Table 2. 4 Limitation of fineness modulus as guideline for different sand category.

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

IV.Shape and Surface Texture

The shape of the aggregate particles influences paste demand, placement characteristics such as workability, strength and cost. Shape is related to sphericity, form, angularity, and roundness. [16] 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 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:

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 [9].

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.

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

2.4. 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 [12].

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 [12].

2.5. Ceramics

Ceramics is nonmetallic solid which is inorganic, produced by the action of heat and subsequent cooling. The structure of ceramics materials may be crystalline or non-crystalline or amorphous. Since most common ceramics are available in crystalline form, the term ceramics is often referred to inorganic crystalline materials. The earliest ceramics made by humans were pottery objects, including 27,000-year-old figurines, made clay, either by itself or mixed with other materials, hardened in fire. Ceramics now include domestic, industrial and building products and a wide range of ceramic art. In 20^{th} century, new ceramics materials were developed for use in advanced ceramic engineering. For example, semi-conductors [5].So, in this study the non-crystalline type of materials are used.

Table 2. 5 Chemical properties of ceramic [17]

Materials	Percent	Materials	Percent	Materials	Percent
SiO_2	68.85	Na_2O	2.01	MnO	0.078
Al_2O_3	18.53	K_2O	1.63	P_2O_5	0.034
Fe_2O_3	4.81	MgO	0.72	SO_3	0.06
CaO	1.57	TiO_2	0.737	LOI	0.48

2.5.1. Ceramic waste

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. [17]. In ceramic industry, about 30% production goes waste. This waste is not recycled in any way form at present. However, ceramic waste is durable, hard and highly resistant to biological and chemical and physical degradation forces. As the ceramic waste is piling up every day, there is a pressure on ceramic industries to find a solution for disposal. The conventional crushed stone aggregate reserves are depleting fast, particularly in some desert regions of the world. Developments of concrete with non-conventional aggregates such waste aggregate and stone dust were used in concrete to improve the properties of concrete and to reduce cost. [3]

Ceramic wastes can be separated into two categories in accordance with the source of raw materials. Those are all fired wastes generated by the structural factories that use only red pastes to manufacture their products such as blocks, roof tiles and bricks and all fired waste produced in stoneware ceramic such as wall, sanitary tile and floor tiles. [17]

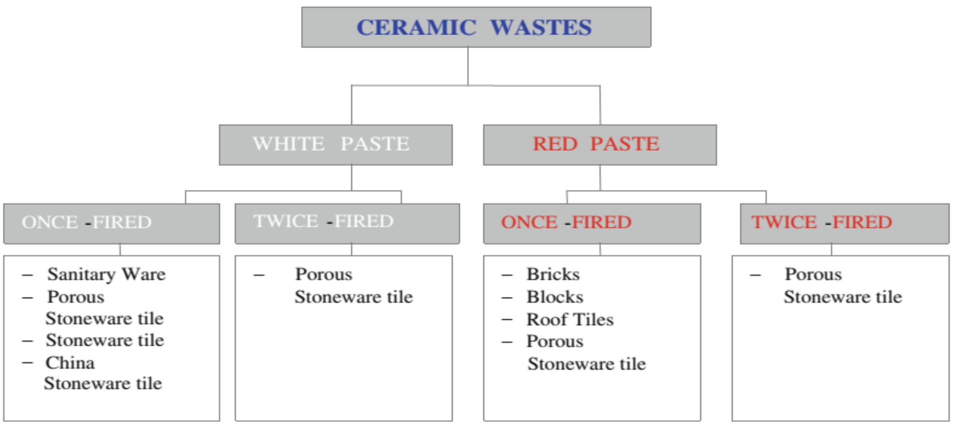


Figure 2- 2:Classification of ceramic wastes by type and production process [17]

2.5.2.Source of ceramic waste

Various products of ceramic wastes include sanitary ware, floor tiles, wall tiles, roof tiles, and ceramics from refractory and vitrified clay tiles. Ceramic waste may come from two sources; [18]

- From ceramic industry, and this waste is classified as non-hazardous industrial waste (NHIW)

- The second source of ceramic waste is associated with construction and demolition activity. For this project work ceramic waste from building construction and demolition waste used.

2.5.3. Physical properties of ceramic waste

The absorption capacity represents the maximum amount of water the aggregates can absorb. For common aggregates, the absorption capacities are order of 0.5% to 2%. Absorption capacities greater than 2% often indication that the aggregates in content may have a potential durability problem. For most of the ceramic waste aggregates a slight increase of compressive strength is evident in different substitution percentages, unfortunately the value is varied considerably even within the same study. [19]

Density of aggregates

Aggregates are also classified into three based on the unit weight of aggregates, for light weight of $1200\,Kg/m^3$,normal weight of $1500\,Kg/m^3$ and heavy weight aggregates $2000\,Kg/m^3$.The density of normal concrete between $2200\ Kg/m^3 - 2600\,Kg/m^3$ and that of light weight concrete is around $2000\ \ Kg/m^3$. [20]

Shape and Texture of the Ceramic waste Aggregate

Surface texture is the property, which influences the bond strength between the cement paste and aggregate. The surface texture of aggregate may be either polished or dull. This depends on the hardness, grain size and pore structure of the rocks. Visually ceramics waste aggregate has two clear distinguishable parts, one of its external with glaze and internal comprising with composition matrix. Based on the surface characteristics. [21] Classifies the aggregate as glassy, smooth, granular, crystalline and porous. The important specification of coarse aggregate is its shape, texture and the maximum size, as in further ceramic waste aggregate was found to be smoother than that of ordinary crushed stone aggregate. [20]

Study on effective Utilization of ceramic waste as recycled coarse aggregate. It was produced by crushing ceramic waste and its shape curve of recycled ceramic aggregate was similar to the natural coarse aggregate. Irregular shape of aggregate was presented in the ceramic waste, resulted that superior surface area and better bonding was absorbed in experimentation. [22]

Table 2. 6 Physical properties of different coarse aggregate [3]

Aggregate	Specific gravity	Maximum size(mm)	FM	Water absorption (%)	Bulk density (kg/m3)	Crushing value (%)	Abrasion value (%)
Crushed stone	2.68	20	6.95	1.2	1566	24	20
Ceramic waste	2.45	20	6.88	0.72	1325	27	28

Stress strain curves

Incorporation of ceramic waste as coarse aggregate in concrete has noticeable influence on the stress- strain curves (SSC) of concrete. Nonetheless, the shape of the stress–strain curve for all the concrete with ceramic waste as coarse aggregate was similar to that of the natural coarse aggregate concrete, regardless of the replacement percentage.

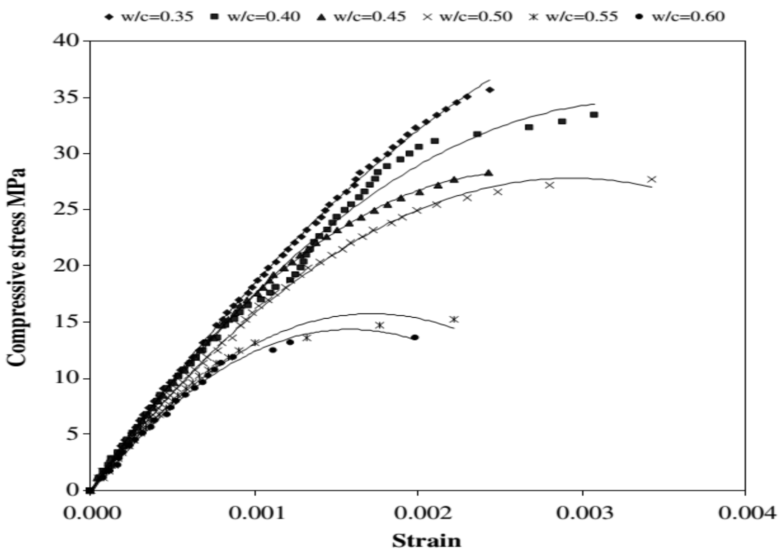


Figure 2-3:Relationship between stress and strain for ceramic waste coarse aggregate concrete. [3]

Figure 2.3 Shows the stress-strain behavior of ceramic waste coarse aggregate concrete. The modulus of elasticity of ceramic waste coarse aggregate concrete varied from $22.2\ to\ 16.1\ GPa$. This is $13.6\%\ to\ 2.4\%$ lower compared to conventional concrete. [3]

2.5.4. Properties of concrete that were made from ceramic waste aggregate

Fresh ceramic waste coarse aggregate concrete more less cohesive and workable than conventional concrete because high water absorption of ceramic waste. [5] Research found that large differences in early curing ages and smaller differences at long curing ages. The result indicates that compressive strength of both concrete with replacement ceramic coarse aggregates and ceramic sand are higher than conventional concrete (control).

It shows that using tile as a coarse aggregate not only cause no reduction in the strength of concrete, but also increase the compressive strength of it up to 30 percent and in higher percent (up to 40 percent) bear no negative impact on compressive strength. [4]

2.6.Cement

Cement paste is the binder in concrete or mortar that holds the fine aggregate, coarse aggregate or other constituents together in a hardened mass. The properties of concrete depend on the quantities and qualities of its constituents. Because cement is the most active component of concrete and usually has greatest unit cost, its selection and proper use are important in obtaining most economically the balance of properties desired for a particular concrete mixture. Most cement will provide adequate levels of strength and durability for general use. It is usually satisfactory and advisable to use general-purpose cement that is readily obtainable locally. When such cement is manufactured and used in large quantity, it is likely to be uniform and its performance under local conditions will be known.

2.7. Stone dust

2.7.1. General

Stone dust is obtained from stone quarries as waste material while crushing stones, stone crusher dust, which is available abundantly from crusher units. Stone dust is a byproduct of the crushing process which contains particle size from 0.75 to 5 mm. For these study stone dusts from crushing stone which passing through No.4 (4.75mm) sieve and retained on $No. 200(75\ \mu m)$ sieve will be use.

Aggregate content is a factor, which has direct and far-reaching effects on both the quality and cost of concrete. Unlike water and cement, which do not alter in any particular characteristic except in the quantity in which they are used, the aggregate component is infinitely variable in terms of shape and grading.

2.7.2. Physical properties of stone dust

Fineness modulus and Specific gravity of stone dust were 2.60 and 2.40 respectively. The particle size distribution curve (PSD), for stone dust sand is high in proportions of fines, as opposed to what is normal for natural sand. The best result is expected with a blend of natural and stone dust sand proportions depending on properties for specific production process.

Particle size distribution curve of stone dust (SD) and natural fine aggregate for the recorded sieve analysis test result shown in fig. below. [23]

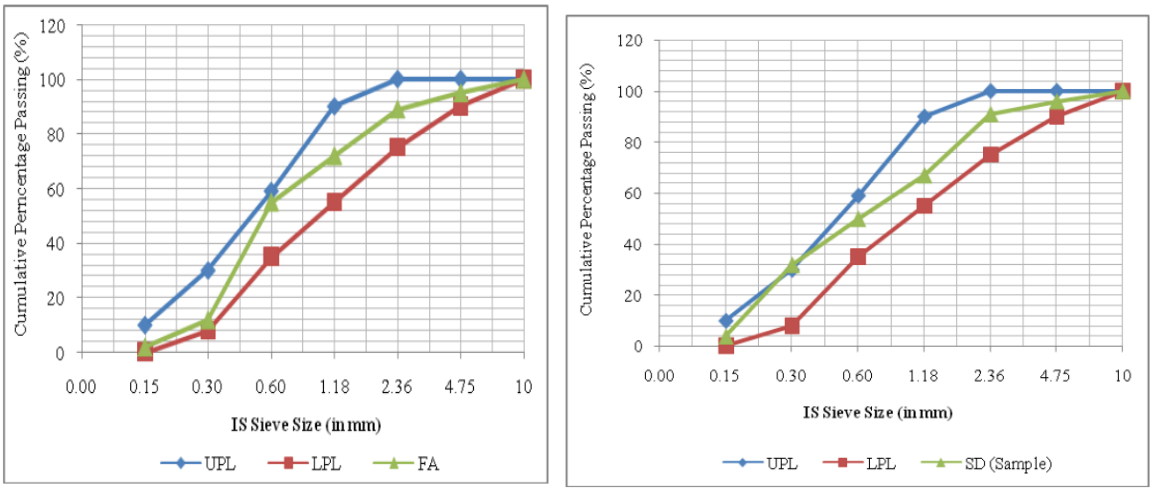


Figure 2- 4 :Particle size distribution of fine aggregate and stone dust. [23]

2.7.3. Benefits of using stone dust in concrete

Crushed fine aggregate reduces the cost of construction. Helps to reduce the impact of the environment by consuming the material generally considered as a waste product. Stone crusher dust can be used in concrete without significant difference in strength and workability compared to concrete with natural sand. The Crushed fine aggregate has potential as fine aggregate in concrete structures with reduction in the cost of construction of concrete by about 20% compared to conventional concrete. Crushed fine aggregate provides stronger bond with cement. [24] The use of stone dust in concrete is beneficial in different manner such as environmental aspects, non-availability of good quality of fine aggregate, strength criteria etc. [25]

One of the main challenges in aggregate production, especially when producing crushed aggregates from hard rock quarries is to obtain a satisfactory mass balance. Any excess fraction that has to be kept on stock or even more deposited will create an economic as well as an environmental problem.

Table 2. 7 Comparison between natural and manufactured sand [27]

Natural sand	Manufactured sand
Has enough fines	Has lots of fines
Has smooth surface	Provide stable grain distribution
Has good shape for concrete pumps	Grains have sharp edges and sometimes irregular
Need less water for concrete pumps therefore, less cement	Needs more water
Economical concrete production	The concrete is more expensive
Surface is smooth and weathered	Surface is rough
Rounded to sub angular in shape	Particles are angular

2.7.4. Stress-strain curves

Incorporation of quarry dust as fine aggregate in concrete has noticeable influence on the stress-strain curves (SSC) of concrete. Nonetheless, the shape of the stress–strain curve for all the concrete with quarry dust fine aggregate was similar to that of the natural sand concrete, regardless of the replacement percentage. From stress-strain diagram we seen that strains were higher for 100% sand replacement than for 0% sand replacement. The grading properties and the fines content of quarry dust may have contributed to the characteristics of stress-strain curve of concrete with quarry dust. The maximum strains for 100% sand replaced concrete is about 15% higher than those of 0% sand replacement. The main cause of the increase in the peak strain is lower modulus of elasticity, which causes the concrete to undergo larger deformation. [26]

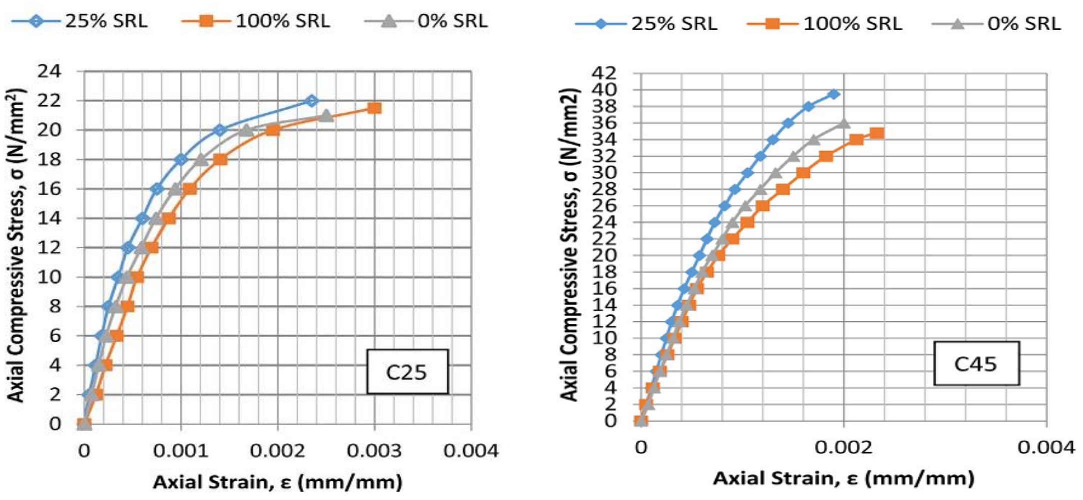


Figure 2-5:Typical axial compressive stress-strain curves for concrete grades C 25 and C 45. [26]

[27]Conducted on the study of properties of concrete using stone dust and demolished concrete waste as partial replacement of fine and coarse aggregate respectively. The percentage replacement of fine aggregate with stone dust and coarse aggregate with demolished concrete waste is 5% to 50% with interval of 5%. The specimens were casted in M40 grade of concrete. The tests were conducted on compressive strength, split tensile strength and flexural strength of normal strength concrete with partial replacement of fine aggregate by stone dust and coarse aggregate by demolished concrete waste, with water cement ratio of 0.37% is studied. From test results it was observed that the stone dust and demolished concrete waste have a potential to provide alternative to conventional fine aggregate and coarse aggregate and help in maintaining the environmental as well as economically balance. It was concluded that the compressive, split tensile and flexural strength of concrete up to 25% replacement of fine aggregate and that of up to 20% replacement of demolished concrete waste reveals approximately same strength as compared to concrete made by conventional coarse aggregate.

[28] Conducted on the experimental study on partial replacement of coarse aggregate by bamboo and fine aggregate by quarry dust in concrete production. The percentage replacement of coarse aggregate by bamboo and fine aggregate by quarry dust is 0% to 25% with interval of 5%. The specimens were cast in M40. Tests were conducted on compressive strength, flexural strength and split tensile strength at the age of 28 days. From test results it was observed that the compressive strength at age of 28 days replacement of coarse and fine aggregates by bamboo and quarry dust is maximum at 15% respectively. It was concluded that the mechanical strength of concrete with partial replacement of coarse aggregate by bamboo

and fine aggregate by quarry dust at 15% is optimum level, which evident from the 28 days strength results. The fresh concrete mix were prepared by OPC as source material and the coarse aggregates with optimum replacement of 15% bamboo in addition to this the fine aggregate was replaced by quarry dust 15, 20, 25% respectively, and investigated the fresh concrete behavior. From the results, the slump values are gradually decreasing while increasing the quarry dust percentage. Similar results were found in compaction factor and workability flow table values. The Vee Bee consistency values are increased while increasing the addition of Quarry dust. The results show the addition of quarry dust increase the water demand as well as decreasing the flow values.

2.8. Concrete Damaged Plasticity Model

CDP is continuum, plasticity-based, damage model for concrete. It assumes that the main two failure mechanisms are tensile cracking and compressive crushing of the concrete material. The evolution of the yield (failure) surface is controlled by two hardening variables and, linked to failure mechanism under tension and compression loading, respectively.

2.8.1 Uniaxial tension and compression stress behavior

The model assumes that the uniaxial tensile and compressive response of concrete is characterized by damaged plasticity, as shown in Figure 2.6. The failure stress corresponds to the onset of micro-cracking in the concrete material. Beyond the failure stress the formation of micro-cracks is represented macroscopically with a softening stress-strain response, which induces strain localization in the concrete structure. Under uniaxial compression the response is linear until the value of initial yield stress, σ_{c0}, In the plastic regime the response is typically characterized by stress hardening followed by strain softening beyond the ultimate stress, σ_{cu}. This representation, although somewhat simplified, captures the main features of the response of concrete.

The damage variables can take values from zero, representing the undamaged material, to one, which represents total loss of strength.

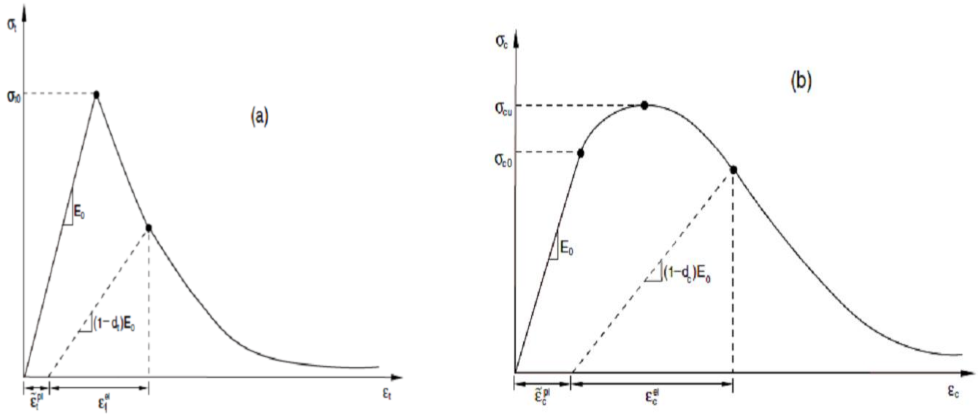


Figure 2- 6: Response of concrete to uniaxial loading in (a) tension and (b) compression [29]

If E_0 is the initial (undamaged) elastic stiffness of the material, the stress-strain relations under uniaxial tension and compression loading are, respectively [29]

$$\sigma_t = (1 - d_t)E_0\left(\varepsilon_t - \check{\varepsilon}_t^{pl}\right) \qquad Equ. 4$$

$$\sigma_c = (1 - d_c)E_0\left(\varepsilon_c - \check{\varepsilon}_c^{pl}\right) \qquad Equ. 5$$

2.8.2 Defining tension stiffening

The post-failure behavior for direct straining is modeled with tension stiffening, which allows you to define the strain-softening behavior for cracked concrete. This behavior also allows for the effects of the reinforcement interaction with concrete to be simulated in a simple manner. Tension stiffening is required in the concrete damaged plasticity model. Tension stiffening can specify by means of a post-failure stress-strain relation or by applying a fracture energy cracking criterion.

2.8.3 post-failure stress-strain relation

In reinforced concrete the specification of post-failure behavior generally means giving the post failure stress as a function of cracking strain. $\tilde{\varepsilon}_t^{ck}$. The cracking strain is defined as the total strain minus the elastic strain corresponding to the undamaged material; that is, $\tilde{\varepsilon}_t^{ck} = \varepsilon_t - \varepsilon_{ot}^{el}$, where $\varepsilon_{ot}^{el} = \sigma_t / E_0$, as illustrated in Figure 2.7. To avoid potential numerical problems, ABAQUS enforces a lower limit on the post-failure stress equal to one hundred of the initial failure stresses: $\sigma_t \geq \sigma_{to}/100$.

Tension stiffening data are given in terms of the cracking strain, $\tilde{\varepsilon}_t^{ck}$. ABAQUS automatically converts the cracking strain values to plastic strain values using the relationship

$$\tilde{\varepsilon}_t^{pl} = \tilde{\varepsilon}_t^{ck} - \frac{d_t}{(1-d_t)}\frac{\sigma_t}{E_0} \qquad Equ.6$$

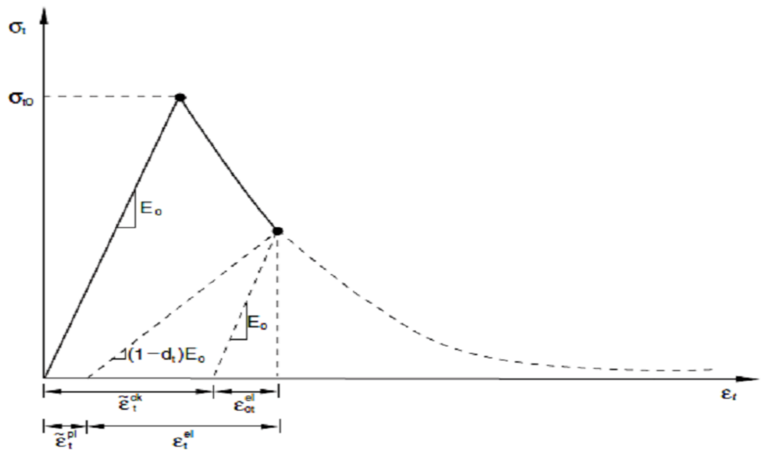


Figure 2- 7: Illustration of the definition of the cracking strain $\tilde{\varepsilon}_t^{ck}$ used for the definition of tension stiffening data.

CHAPTER THREE

MATERIALS AND RESEARCH METHODOLOGY

3.1 General

To attain the stated objectives, the research basically focuses on laboratory investigations of concrete samples prepared and analytical simulation on the sample prepared for the flexural beam to validate the result from laboratory test. The specimens are prepared with changing amount of ceramic waste as coarse aggregate and stone dust as fine aggregate. The ACI mix design method was prepared for $C-25$ grade concrete used in determining the mix proportions after all the required parameters have been obtained a prior. These include the studying physical properties of materials, sieve analysis of both the fine and coarse aggregates and their specific gravity.

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, split tensile and flexural strength tests have been carried out at ages of 7,14 and 28 days.

The validation was done by using Finite element simulation called ABACUS on the flexural beam peak load and modulus rupture what researcher done in laboratory. At the end conclusion and recommendation were drawn and forwarded from the result observed.

3.2 Materials

Materials that have used in the investigation are cement, aggregate, water, ceramic waste and stone dust. In reference to this study, conventional concrete signifies the usual concrete with grade of C-25 which contains cement, water and aggregates as a basic constituent. To construct the hybrid and mono concrete sample Pozzolana Portland cement, sand, coarse aggregate, washed stone dust, ceramic waste, mixing and placing equipment's were used. For the experimental set up universal testing machines was also used in order to test the flexural, compressive and tensile strength of the concrete.

3.3 Data Preparation and Analysis

The data was analyzed and interpreted using laboratory experiment.

1. Material Tests

Tests were conducted on the raw materials to determine their properties and suitability for this experiment

2. Mix Proportioning (Mix Design)

Total of 5 mixes with concrete grade of $C-25$ were produced. It was prepared with coarse aggregate replace by 5% ,10%, 15% and 20% of the ceramic waste aggregate and fine aggregate replacements by 25%, 50%, 75%, and 100% of the stone dust aggregate by weight proportion. And the strength of concrete was done without any admixture on the mix. A control mix with no ceramic waste aggregate and stone dust replacement was produced to make a comparative analysis.

3. Specimen preparation

The concrete test specimens were conducted in the Jimma University, Jimma Institute Technology and Construction Material Testing Laboratory. The prepared samples were consisting of concrete cubes, cylinders and beams.

4. Testing of Specimens

The tests were conducted on samples of concrete that prepared in laboratory. The tests which will be conducted are slump test, compaction factor test, compressive strength, split tensile strength and flexural strength.

3.4 Study Variables

3.4.1 Dependent variables

- Concrete workability
- Concrete Split tensile strength
- Concrete Compressive strength
- Concrete flexural strength

- Concrete stress and strain diagram

3.4.2 Independent Variables

- Percentage of Ceramic waste
- Percentage of stone dust

3.5 Sources of Data

The sample sizes that have from the study are just the representative samples size at different types of coarse aggregates and fine aggregates. For different curing days independently three samples took for compressive, split tensile and flexural strength test with five different types of mixes and this summarized as 45 cube specimens, 45 cylinders and 45 flexural beam specimens. Samples were taken from ceramics waste tiles from Jimma University and Jimma town from different building finishing, maintenance and renovation works as wastes and by manual crushing of hammer with a considerable approximate size of maximum 20mm.Stone dust were taken from Jimma town around setu semuru (Furustale) stone quarrying. River Sands of Chaweqa 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.

Table 3. 1 Total number of samples

Designation code	Samples								
	Cubes			Cylinders			Beams		
	7 days	14 days	28 days	7 days	14days	28 days	7 days	14 days	28 days
M 00	3	3	3	3	3	3	3	3	3
M 25	3	3	3	3	3	3	3	3	3
M 50	3	3	3	3	3	3	3	3	3
M 75	3	3	3	3	3	3	3	3	3
M 100	3	3	3	3	3	3	3	3	3
Total	45			45			45		

3.6 Experimental Works Procedure

Stage 1: Sampling preparation stage

- Coarse Aggregate: - For this study the concrete mixes by Crushed basaltic stone, the same coarse aggregate taken from "Jimma" crushing plant crushed stone "was used.
- Ceramic waste tiles crushed manually with a hammer by guessing towards the nominal maximum size of coarse aggregate at a laboratory
- Fine Aggregate (Sand): - Chaweqa Sand sample prepared for both control and partial replacement test for concrete mix, the un-washed sand sample was taken.
- Stone dust fine aggregate which passing on sieve No.4.75 and retained on the sieve no $150\mu m$ are used in the property test.

Stage 2: Materials tests in concrete in laboratory tests

- Tests on coarse aggregate according to ASTM 136, ASTM C 127, ASTM C 29/C 29M, and BS Standard Procedures. (i.e., sieve analysis, water absorption, specific gravity, moisture content, unit weight)
- 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, water absorption, specific gravity, moisture, unit weight, bulking of sand and Silt content).

Stage 3: Mix design

1.Mix design procedures as per ACI

Collected data from Test results of aggregate for mix design.

Specific gravity for course and fine aggregate is 2.65 and 2.44 respectively

Specific gravity of pozzolana Portland cement is 2.9

Unit weight of dry rodded course and fine aggregate is 1717Kg/m3 and 1669Kg/m3 respectively

Water absorption for course and fine aggregate is 0.6%and 1.2% respectively

Free surface Moisture content in course and fine aggregate 0.75 % & 0.603% respectively

Fineness modulus of fine aggregate = 2.3

Step 1. Choice of the slump. The expected slump for workability is 25mm - 100mm.

Step 2. Choice of nominal maximum aggregate size. The coarse aggregate used for this study has nominal maximum size of 20mm and air content in volume of concrete is 2%

Step 3. Estimation of mixing water and air content. The concrete is non-air entrained since the structure is not exposed to sever weathering as per ACI code for 20mm aggregate size the total density of water is 185 Kg/m3

Step 4. Selection of water cement ratio (w/c). The water cement ratio was required for non-air entrained concrete of 25Mpa compressive strength.

- From strength point of view the estimated water-cement ratio is 0.62
- From the Exposure condition the estimated water to cement ratio is 0.5

Taking the minimum of the two values, the adopted water-cement ratio to be used for the mix design is 0.5.

Step 5. Calculation of cement content. The amount of cement per unit volume of concrete is fixed based on the determination made in step 3 and step 4. The required cement is equal to the estimated mixing water (in step 3) divided by water cement ratio (step 4).

$$\text{Cement} = \frac{185}{0.5} = 370\text{kg/m3}$$

Step 6. Estimation of coarse aggregate content. The quantity of coarse aggregate is estimated from bulk volume of dry rodded gravel. From ACI table 11.4 for maximum nominal size of gravel 20mm and fineness modulus of fine aggregate 2.3~2.4, the volume of dry rodded coarse aggregate is 0.66 per unit volume of concrete.

The quantity of coarse aggregate is

0.66*1717Kg/m3 = 1133.22 Kg/m3

Step 7. Estimation of fine aggregate content. From ACI table 11.9 the first estimate density of fresh concrete for 20mm maximum size of aggregate and non-air entrained concrete is 2355 Kg/m3

Weight of fine aggregate = 2355-(185+370+1133.22) = 666.78kg/m3

In Volume method, the absolute volume of mix ingredients per unit cubic meter volume of concrete on volume basis is

$$\text{Volume} = \frac{\text{weight}}{\text{Specific gravity} * \text{unit weight of water}}$$

Item no	Ingredient	Weight (kg/m3)	Absolute Volume(cm3)
1	Cement	370	$127.6*10^3$
2	water	185	$185*10^3$
3	Gravel	1133.22	$427.63*10^3$
4	Air	-	$20*10^3$

Therefore, absolute volume of fine aggregate = (1000-760.22) $*10^3$= $240*10^3$

Absolute weight of fine aggregate = 240*2.44= 585 kg/m3

Adjustment for field condition of ingredients

Ingredients	Cement	sand	gravel	water
Quantity(kg/m3)	370	666.8	1133.22	185
Ratio	1	1.8	3.1	0.50
Quantity in(kg)	50	90.11	153.14	25.00

Step 8. Field Adjustment for moisture in the Aggregate. Since the aggregates will be neither Surface Saturated (SSD) nor Oven Dry (OD) in the field, it is necessary to adjust the aggregate weights for the amount of water contained in the aggregate. Since absorbed water does not become part of the mix water, only surface water needs to be considered.

Final design mix proportion of ingredients.

Ingredients	Cement	sand	gravel	water
Quantity(kg/m3)	370	670.8	1140	187.3
Ratio	1	1.8	3.1	0.51
Quantity in(kg)	50	91	154	25.00

Weight of different sample proportion in mix

Designation code	Cement (Kg)	Sand (Kg)	Stone dust (Kg)	Gravel (Kg)	Ceramic waste (Kg)	Water (Kg)
M00	37.2	63.25	0.00	112.35	0.00	19.72
M25	37.2	47.91	15.84	106.73	5.62	19.72
M50	37.2	31.63	31.62	101.11	11.24	19.72
M75	37.2	15.84	47.44	95.49	16.86	19.72
M100	37.2	0.00	63.25	89.87	22.48	19.72
Total	**186**	**158.25**	**158.25**	**505.55**	**56.20**	**98.6**

2. Mixing of concrete by different percentage content coarse aggregate crushed basaltic stone replacing by 5% ,10% , 15% and 20% of ceramic waste in all mix and interchangeable fine aggregate Chaweka river sand 75% and stone dust of 25% , 50%% of Chaweka river and 50% of stone dust, 25% of Chaweqa river sand and 75% of stone dust, and 0% of chaweqa sand and 100% stone dust, but Cement and water are constant for all C-25 concrete mix. For this at least three cubes of $150mm \times 150mm \times 150\ mm$, three flexural $100mm \times 100mm \times 500mm$, three-cylinder $100\ mm$ (dia) and $200mm$ height and also for slump test of concrete have been made for consecutive mix and test 7th, 14th, and 28th days.
3. The slump test was done in order to check the workability of the concrete and also prepared three samples of concrete cubes, three samples of concrete cylinders and three samples of flexural were casted from different types and percentages of aggregate within a day of 7th, 14th and 28th days.

Totally forty-five cubes, forty-five cylinder and forty-five flexural samples were casted by using $150mm \times 150mm \times 150mm$ cubic, cylinder $100mm$ (dia.) and $200mm$ height and $100mm \times 100mm \times 500mm$ flexural cast respectively within a week.

Figure 3: 1 A and B shown concrete cube sample production in the laboratory

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

Removing the cubic and flexural mold with a great care to prevent any damage, external and internal, to the specimen as shown in figure 3.2.

Figure 3: 2 samples of cube and coding the samples respectively

Stage -4: Concrete Compressive, split tensile and flexural strength tests of concrete sample

Stage-5: Analysis and discussion

1. Compare and contrast of the quality and suitability of the coarse aggregate samples and fine aggregate, discussed on the effect of material properties C-25 concrete, workability, unit weight, compressive strength, split tensile and flexural strength of the concrete.
2. Analyzing and discussion on the result from lab by using Tables, Bars, Charts and Graphs.

3.7 Material Preparation and Concrete Production

3.7.1 Material preparation

3.7.1.1 Cement

The cement used for production of concrete was Pozzolana Portland cement (PPC) produce as per $CEM\ I - 32.5$ grade manufactured by Dangote Cement Industries PLC. This cement satisfies the requirements of Ethiopian Standards, ES C. D5 201 and ES 1177-ICEM 1/32.5R (ESA, 2013). The specific gravity of the Dangote PPC was known to have 2.9. The reason to select this cement is due availability other type of cement on the market.

I.Normal Consistency

Prior to the determination of the amount of water required to prepare the cement paste, normal consistency test was performed. Three trials were carried out with different water - cement ratio until the proportional of water in mix achieved for a paste that the rod of Vic at apparatus settles $10 \pm 1\ mm$ below the original surface within 30 seconds. The consistence of PPC in this study is observed at water cement ratio of 33% which have penetration depth of 9mm. The usual range of water - cement ratio for normal consistency is between 26% and 33% (Dinku, 2002). The procedure is presented in see, Appendix. A.

II.Cement Setting Time

The initial and final setting time of Dangote PPC Grade 32.5R CEM was determined by Automatic Vic at Apparatus where the procedure followed the ASTM C191 standards. The cement paste was prepared carefully by using 85% water that gave acceptable normal consistency. The time at which water was first added was taken, and the penetration tests were recorded at the regular time interval of $10\ minute$, then time in minutes was taken when the initial set needle penetrated into the paste to a depth of $25mm$ below the upper edge of the ring that held the paste. Finally, the researcher estimated the final setting time by using the equation according to Jimma laboratory manual reference at 14 pages.

$$Final\ setting\ time\ (in\ minuts) = 90 + 1.2 \times (initial\ setting\ time) \qquad Equ.7$$

3.7.1.2 Aggregate

Aggregates are material used as filler with cement paste in concrete. It is important to obtain right type and quality of aggregate to produce a good quality of concrete since the aggregates occupy more percentages in concrete production by volume.

Fine Aggregate

Fine aggregate serves for filling all the open space between coarse aggregate particles. Thus, it reduces the porosity of final mass and considerably increases concrete strength. Fine aggregate can be naturally available or manufactured by crushing aggregate. In this investigation natural sand taken from Chaweqa river and stone dust was used as partial replacement of fine aggregate. Sieve analysis was conducted to determine the particle size distribution using electric sieve shaker and series of sieve with different sizes in diameter as ASTM specification. The silt content, specific gravity, water absorption, Unit weight, moisture content and bulking of sand were also determined during laboratory test and outlined in appendix A.

Table 3. 2 Standard test methods for fine aggregate

Property tests	Standards
Sieve analysis of fine aggregate	ASTM C 136
Unit weight of fine aggregate	ASTM C127
Silt content of fine aggregate	ASTM C 117
Bulking of sand	IS2386
Specific gravity and absorption of fine aggregate	ASTM C 127
Moisture content of fine aggregate	ASTM C 566

Table 3. 3 Chaweqa sand and stone dust sample summarized physical properties

Fine aggregate	Unit weight Compacted(kg/m3)	Specific gravity (SSD)	Fine's modulus	Absorption capacity (%)	Moisture content (%)	Silt/clay content (%)
Sand (FA)	1565	2.44	2.67	1.11	0.603	3.5
Stone dust	1669	2.615	3.05	1.214	1.01	1.1

Coarse Aggregate

Crushed stone, gravel and broken brick are some of aggregate material which is available as a coarse aggregate in production of concrete. The coarse aggregate used in this research was basaltic crushed rock and ceramic waste aggregate. The aggregate coming from the crushing was washed thoroughly and dried in air inside the laboratory. The size of coarse aggregate used for experimental investigation was 20mm average diameter and it was sieved and stored in different grades for blending purposes to produce a well graded coarse aggregate.

Excess fines of coarse aggregate were removed through the use of sieving with 4.75mm sieve diameter to satisfy the requirement. Fines contain many impurities results in strength loss in the concrete and increase the surface area for water absorption increasing the characteristics of the mix .Therefore, there is a need to sieve the aggregates to reduce the number of fines. During experimental work the properties of coarse aggregate testes done were specific gravity, water absorption, sieve analysis, moisture content and unit weight. The test procedures and results were outlined in Appendix A.

Table 3. 4 Standard test method for coarse aggregate

Property Tests	Standards
Sieve analysis of coarse aggregate	ASTM C 136, C33
Unit weight of coarse aggregate	ASTM C29
Specific gravity and absorption of coarse aggregate	ASTM C127
Moisture content of coarse aggregate	ASTM C566

(a). Basaltic coarse aggregate (b). waste ceramic aggregate

Figure 3: 3 coarse aggregate types for the laboratory experiment as samples

Table 3. 5 Physical characteristics and properties of different types of coarse aggregate summary

Coarse aggregate	Unit weight Compacted (kg/m3)	Specific gravity (SSD)	Fine's modulus	Absorption capacity (%)	Moisture content (%)	Size of aggregate in mm
Basaltic stone	1717	2.41	4.91	0.75	0.865	20
Ceramic waste	1520.66	2.565	4.87	0.94	1.79	20

Flakiness Index

Flaky aggregate is defined as an aggregate particle with a least dimension (thickness) less than 0.6 of the mean of the smallest sieve size through which the particle passes and the largest sieve size on which the particle retained. Flaky aggregate tends to reduces seals with less voids due to their tendency to pack more tightly than cubical aggregates consequently flaky particles require less binder.

Flakiness index is defined as the percentage (by mass) of stones in an aggregate having an average least dimension (ALD) of less than 0.6 times their average dimension. It is determined by: -

$$FI = \frac{w}{W} * 100\% \qquad Equ. 8$$

Where W= Total weight of the fraction

W= Total weight of passing fraction

As per IS flakiness Index in excess of 35% to 40% is considered undesirable and no limit are known as yet for Elongation Index.

As per BS812, the allowable limits for F.I for coarse aggregate is maximum of 35%. For the procedure to determine the FI see Appendix A.

Table 3. 6 Flakiness index Value of blended of the basaltic and CW coarse aggregate

Designation code	Flakiness Index (FI) (%)
$0\%\ CW\ and\ 0\%\ SD$	11.19
$5\%\ CW\ and\ 25\%\ SD$	15.84
$10\%\ CW\ and\ 50\%\ SD$	21.41
$15\%\ CW\ and\ 75\%\ SD$	27.34
$20\%\ CW\ and\ 100\%\ SD$	29.32

3.7.1.3 Water Used for the Experiment

Water is a very important component in the concrete production. The optimum content of water gives good concrete strength. Water is important since it hydrates the cement and makes concrete workable. Generally, water that is satisfactory for drinking is also suitable for use in concrete. In this work portable water suitable for human consumption, fresh, clean, free from organic impurities and salt was employed in the experimental procedures.

3.7.2 Concrete Mixes

3.7.2.1 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 25Mpa with 28 days curing and a water cement ratio of 0.51 since the required minimum strength is $25Mpa$ at 28 days and in non-air entrained condition. On this base; five 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 and fine aggregate samples used as a control and the others are substitution in different percentage and fully substitution by the experimental coarse and fine aggregates without any admixtures. The quantity of concrete materials was calculated by using the physical properties of the materials

3.1.1.1. Concrete Specimens and Mixing Procedures

The concrete test specimen cube, cylinder 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, coarse aggregate and water were measured to an accuracy of $0.1g$m balance. After that the weighted coarse aggregate in required percentage proportion, coarse aggregate was first added into mixer 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.

Figure 3: 4 Concrete mixing

3.1.1.2. Casting

Proportionally mixed concrete was placed in the molds of cubes, cylinders 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 ($150mm \times 150mm \times 150mm$) size, three cylinders molds having 100mm diameter and $200\ mm$ height, and three flexures having ($100mm \times 100mm \times 500mm$) were nominal compulsory; thus, were casted for compressive, split tensile, and flexural strength testing.

Figure 3: 5 Concrete casting

3.1.1.3. Curing

The concrete blend changed into casted with inside the molds for the primary 24 hours. After that, the concrete was removed from the molds and placed in a water bath at a temperature of $23 \pm 1\ {}^{0}C$ for curing to take place until the testing age was reached in the anticipated curing age.

3.2. Test in Concrete production

3.8.1 Test for Fresh Concrete

Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work. The slump of the concrete is measured by measuring the distance from the top of the slumped concrete to the level of the top of the slump cone.

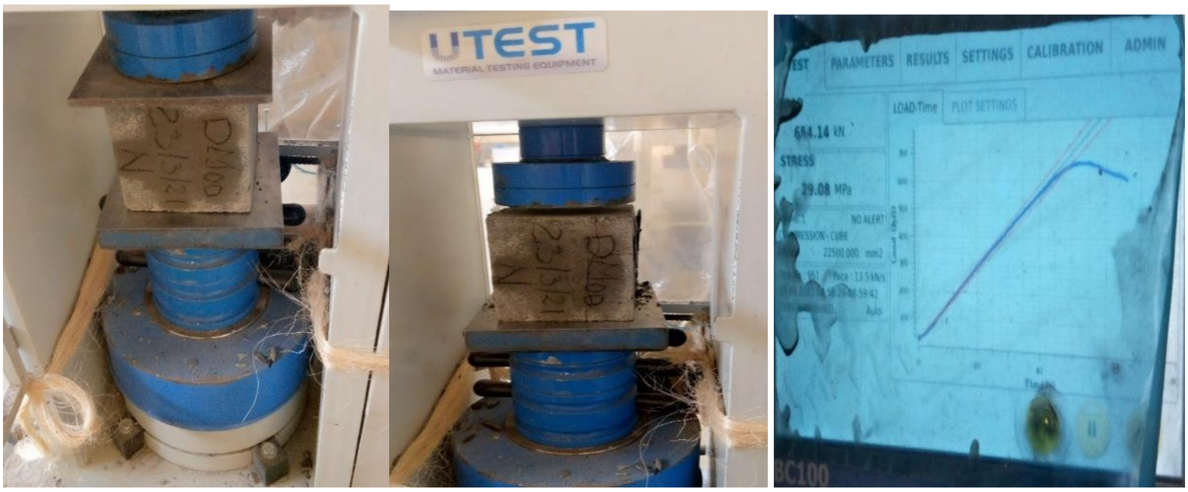
The slump test procedure according to ASTM C143 dampens the mold and place it on a flat, moist, nonabsorbent surface. It shall be held firmly in place during filling by the operator standing on the two-foot pieces. From the sample of concrete obtained in accordance with immediately fill the mold in three layers, each layer is one third the volume of the mold by rodding each layer with 25 times. slump was measured as shown in Figure 3.6.

Figure 3: 6 Slump test of concrete

3.2.1. Test for Hardened Concrete

3.8.2.1 Compressive Strength Concrete

In the 7th, 14th and 28th days of curing period the concrete cubes specimens were 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. Finally, the specimens were tested by compression testing machine. Loading Rate for 150 mm cube was 140 Kg/cm^2 per minute till the Specimens fails for cube test.



a) Cube specimen ready for test b) concrete cube sample after test (c) stress from UTM

Figure 3: 7 a. Cube specimen ready for test and b concrete cube sample after test

3.8.2.2 Flexural Strength of Concrete

According to concrete laboratory manual (Dinku,2002) and ASTMC-78, to determine flexural strength of concrete, the concrete should be kept in the mold for 24hours.The load concrete specimens to failure at 7, 14 and 28 days of curing by using testing machine and record the failure load. In this test, the concrete sample to be tested was supported at 30mm towards its both ends and loaded at the center the load a gradually failure as illustrated in the Figure 3.8. The failure load at which the concrete cracks was then recorded in KN.

To determine the flexural strength of reinforced concrete using the calculation formula for two-point loads:

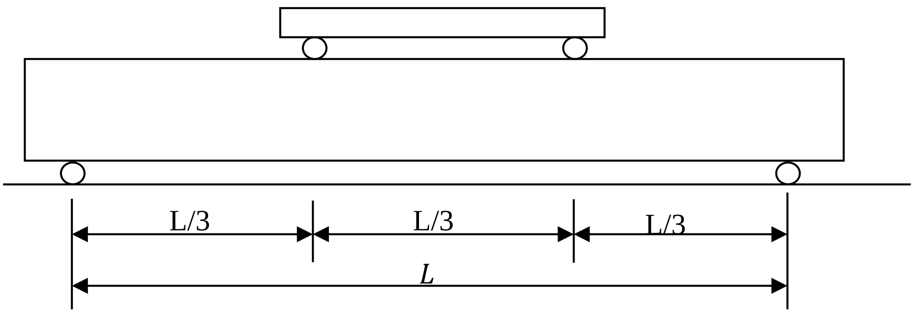


Figure 3: 8 Two-point loading of beam specimen

a) If failure with in the middle third of the span

$$R = \frac{PL}{bd^2} \qquad Equ. 9$$

Where:

P = *the peak load*

L = the distance between the lower supporting roller

b = breadth of the beam

d = depth of the beam

b) If the failure occurs outside the middle third of the span length by not more than 5% of the span length

$$R = \frac{3Pa}{bd^2} \qquad Equ. 10$$

Where: a = average distance between line of fracture and the nearest support measured on the tension surface of the beam

Generally, according to ASTMC- 78, (2004) the formula was applied the fracture initiates in the tension surface within middle third of the span length, shown in Figure 3.9.

Figure 3: 9 Center point loading flexural strength test

3.8.2.3 Split tensile strength Test

No standard tests have been adopted to provide a direct measurement of tensile strength of concrete. The problem of secondary stresses induced through gripping makes the test results difficult either to interpret or produce. The splitting tensile strength test is an indirect tension test for concrete. It is carried out on a standard cylinder, tested on its side in diametric compression as shown in the Figure 3.10. The horizontal stress to which the element is subjected is given by the following equation. Horizontal tension

$$\sigma_t = \frac{2P}{\pi LD} \qquad Equ. 11$$

Where: P − The applied compressive load

L − The cylinder length, and

D − The cylinder diameter

Figure 3: 10 Splitting tensile strength of specimen

3.9 Stress - Strain curve for reinforced concrete

3.9.1 Compressive Stress-Strain Nature of concrete

The complete stress–strain curve of the material in compression is wanted for the analysis and design of structures. In experimental investigation, an attempt has been made to generate the complete stress–strain curve experimentally for partially replacing the coarse aggregate by ceramic waste and fine aggregate by stone dust concrete for compressive strength of $25\ MPa$. The stress verses strain curve is drawn from cube compressive test results. The sample cube prepared from CW and SD in different percentage tested by using universal tested machine.

The stress was calculated using the following formula after the load P was taken with the respective gauge reading change in the compressive testing machine. There is a distinction among the engineering stress and the true stress. By its primary definition the uniaxial stress is given by:

$$\sigma = \frac{P}{A} \qquad Equ.12$$

Where:

σ = Stress for each load types
P = Applied load, A = Initial area of cube

The strain was also calculated for the change of height of cube obtained from the gauge reading divided by the original length of the sample group

$$\varepsilon = \frac{\Delta L}{L} \qquad Equ.13$$

Where:

ε = Strain for each change in length

ΔL = Change in height of cube, L = Original height of cube

3.10. Finite element Model

The finite element analysis program ABAQUS, 6.14.5 is used for the analytical simulation of concrete flexural beam. In order to simulate the actual behavior and represent the real loading condition, beam, support and the interaction constraints have to be modeled properly. The choice of suitable element type and mesh size that can possibly provide acceptable results with reasonable computational time is also important in numerical analysis.

3.10.1. Geometric modeling

Concrete model

Concrete element was modeled as 8-noded linear hexahedral concrete element with reduced integration and hourglass control (C3D8R) was used.

Loading and supporting plates model

Supporting and loading plates that transfer the reaction and loads from to the concrete elements are modeled as solid element similar to the concrete. The approximate mesh size used is similar that used for concrete.

3.10.2 Material modeling

3.10.2.1 Concrete

3.10.2.1.1 Elastic behavior

The elastic behavior was modeled as linear and isotropic, standard values of modulus of elasticity of each concrete according to its grade and according to EBCS EN 1992-1-1: 2013.its value was calculated using the relation presented in equation 3.14

$$E_{cm} = 22\left(\frac{f_{cm}}{10}\right)^{0.3} \qquad Equ. 14$$

Where: $f_{cm} = f_{ck} + 8$, f_{cm} is mean compressive strength of concrete

To completely define the elastic property Poisson's ratio should have to define. From different literature position's ratio of concrete is in the ranges of 0.15-0.2. In this study a value of 0.18 for position's ratio was chosen.

3.10.2.1.2 Damage plasticity model

In order to describe strength with the triaxial stress as input to finite element program ABAQUS, a set of five parameters are required to completely describe the plastic behavior of concrete; dilation angle (ψ), eccentricity (ε), f_{bo}/f_{co} , K_c, and viscosity parameter, the default values are preferred to be used by the ABAQUS and its vales are given on table 3.7.

Table 3. 7 CDP parameter

Dilation angle, ψ	Eccentricity, Ɛ	σ_{b0}/σ_{c0}	K	Viscosity, μ
35°	0.1	1.16	0.667	0.0001

3.10.2.1.3 Compressive behavior

Concrete compressive behavior is input to the ABAQUS can be obtained from laboratory test and normalized by applying the standard equation in CES-149-2015 shown in equation 3.18.

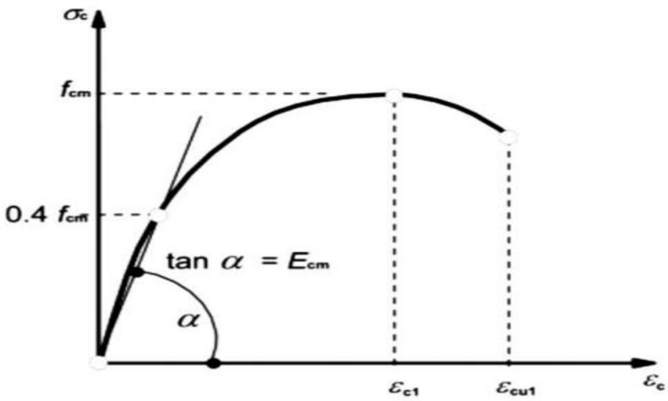


Figure 3: 11 Compression Stress-Strain relation for concrete

$$\sigma_c = f_{cm}\left(\frac{k\eta - \eta^2}{1 + (k-2)\eta}\right) \qquad Equ. 15$$

Where: $\eta = \varepsilon_c/\varepsilon_{c1}$

$And\ \varepsilon_{c1} = 0.7(f_{cm})^{0.31}$, is strain at peak stress according to ES EN 1992-1-1:2015

$k = 1.05E_{cm}\,\varepsilon_{c1}/f_{cm}$, k is factor

$E_{cm=}$ is scant modulus

In CDP models, the plastic hardening strain in compression $\varepsilon_c^{in,h}$ played a key role in finding the relation between the damage parameters and the compressive strength of concrete (see fig2.6b) as follows: -

$$\varepsilon_c^{in,h} = \varepsilon_c - \frac{\sigma_c}{E_0} \qquad Equ. 16$$

Compression damage(d_c) was based on inelastic hardening strain in compression $\varepsilon_c^{in,h}$ that controlled the unloading curve slope. Given that dc increased with respect to an increase in $\varepsilon_c^{in,h}$ it could be expressed as follows: -

$$d_c = 1 - \frac{\sigma_c}{E_0} \qquad Equ. 17$$

3.10.2.1.4 Tensile behavior

Since tensile stiffening affects the result of the analysis and this are considered by using Wang & Hsu formula for the weakening function.

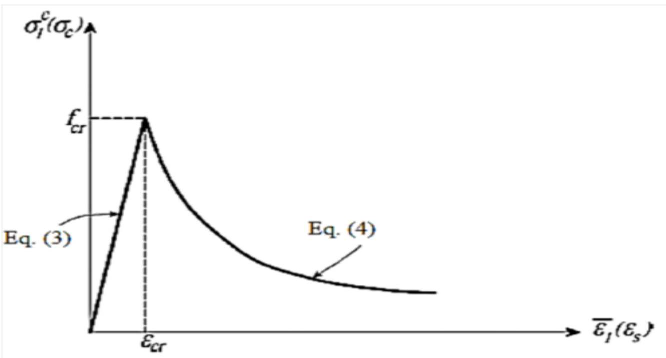


Figure 3: 12 Tensile Stress-Strain relation for concrete

$$\sigma_t = E_{cm}\varepsilon_t \qquad for \quad \varepsilon_t \le \varepsilon_{cr} \qquad Equ. 18$$

$$\sigma_t = f_{ctm}\left(\frac{\varepsilon_{cr}}{\varepsilon_t}\right)^{0.4} \qquad for \quad \varepsilon_t > \varepsilon_{cr} \qquad Equ. 19$$

3.10.3 Step and Interaction Properties

Beside to the initial step in which boundary conditions are defined, additional step, Step-1 is created to apply the axial loading. dynamic, dynamic explicit. Tie constraints were created for the interaction between the concrete beam and steel support at top and bottom. Hence full bonding without slips or sliding condition is idealized at the interface of the two parts. So, both support and beam sections are acting as a single unit.

3.10.4. Loading and Boundary Condition

After modeling and assembling the section appropriate boundary condition were created using the boundary condition option using the initial step. The simple support both end of the concrete beams using pinned option. The pinned connection is the one which displacement in three axes are zero ($u_x = u_y = u_z$ =0) and the rotation axis are equal unit. The loading condition used in this research was expressed in form of displacement and created using boundary condition option in the second step which was created as nonlinear dynamic explicit.

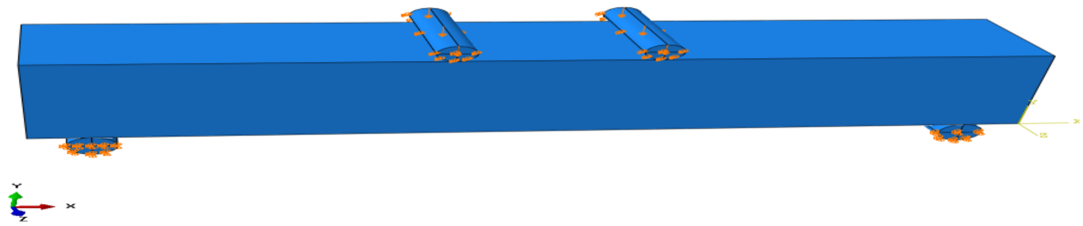


Figure 3: 13 Loading and Boundary condition of Model

3.10.5. Finite Element Mesh

When undertaking any finite element analysis, and in particular a nonlinear analysis, it is extremely important to choose suitable elements and an associated mesh in order to obtain a satisfactory solution to the problem. As the method is approximate, it is important to have a good understanding of the consequences of the assumptions when choosing the element types used and size of mesh. This allows the effects of the approximation to be minimized within the solution. In this study mesh density was investigated for the model, and a mesh size of 15mm for beam and 5mm for support was chosen in each direction. In addition, the selected mesh size maintains a balance between computational time and accuracy of results.

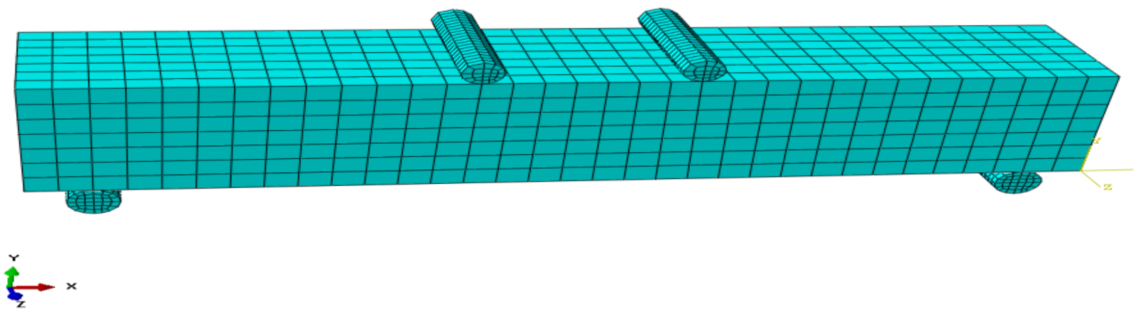


Figure 3: 14 Finite Element Mesh

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Sieve Analysis

Sieve analysis was done to determine the fineness modulus of aggregates and the relative amounts of particle sizes distribution of particle in the aggregate using sieve series of square or round openings starting with the large at the top. The sieve was arranged in descending order of size from top to bottom.

The coarse aggregate sieve analysis was done for coarse aggregates passing sieve size of 37.5mm and retained on sieve size of 4.75mm according to ASTM sieve size. Accordingly, the upper and lower bound limit for the coarse aggregate of ASTM shown in Table 4.2.

Table 4. 1 Sieve analysis for coarse aggregate

Sieve size (mm)	Mass of Samples retained (g)		Avg. Mass retained (g)	% Retained	Cumulative % retained	Cumulative % passing
	s-1	s-2				
37.5	0	0	0	0	0	100
28	410	408	409	4.09	4.09	95.91
19	2353	2289	2321	23.21	27.6	72.4
12.5	4107	4393	4250	42.5	70.1	29.9
9.5	2196	2135	2165.5	21.65	91.75	8.25
4.75	651	459	555	5.55	97.3	2.7
2.36	276	312	274	2.74	99.95	0.05
pan	7	4	5.5	0.05	100	-

Table 4. 2ASTM upper and lower limit of PSD for coarse aggregate

Sieve sizes (mm)	Cumulative % passing		Cumulative % Retained	
	ASTM min	ASTM max	ASTM min	ASTM max
37.5	100	100	0	0
28	90	100	10	0
19	40	85	60	15
12.5	10	40	90	60
9.5	0	15	100	85
4.75	0	5	100	95
pan	0	0	100	100

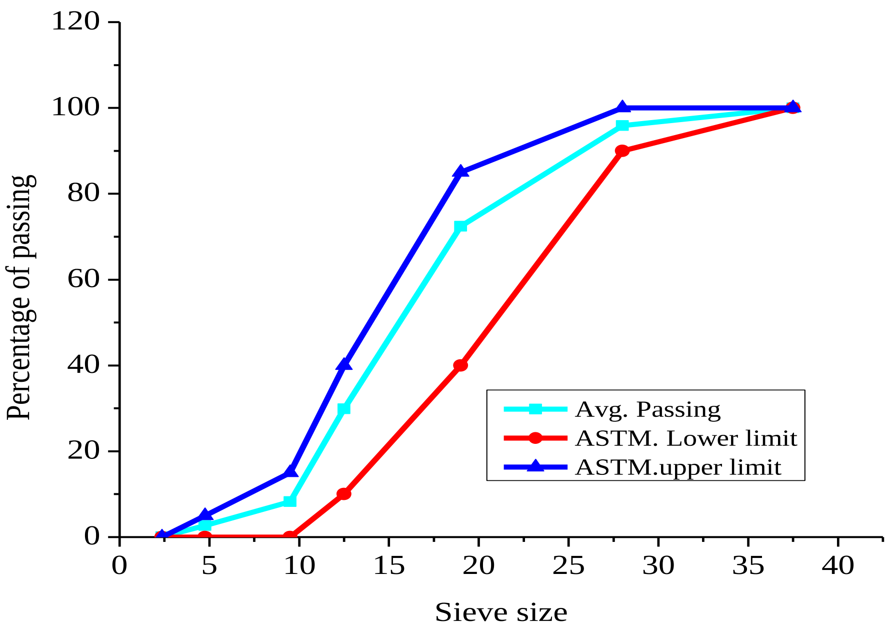


Figure 4-1: Particle size distribution curve for basaltic stone coarse aggregate

The sieve evaluation was done for grinded ceramic waste which was used as partial replacement of Coarse aggregate. This was done to determine that the replacing material shows similar particle size distribution with that of natural coarse aggregate used. From the test result of sieve analysis, the grinded ceramic waste shows almost similar behavior to the natural coarse aggregate and also confirms to ASTM limits of PSD recommendation as shown in table 4.3. The Fineness Modulus of grinded ceramic waste was found to be 4.87.

Table 4. 3 Sieve analysis for ceramic waste

Sieve size (mm)	Mass of Samples retained (gm)		Avg. Mass retained (gm)	% Retained	Cumulative % retained	Cumulative % passing
	S-1	S-2				
37.5	0	0	0	0	0	100
28	171.5	249	210.25	4.205	4.205	95.795
19	1040.5	1031	1035.75	20.715	24.92	75.08
12.5	2162.5	2240	2201.25	44.025	68.945	31.055
9.5	1157.5	1080.5	1119	22.38	91.325	8.675
4.75	355	337	346	6.92	98.245	1.755
2.36	109.5	45	77.25	1.545	99.79	0.21
pan	3.5	17.5	10.5	0.21	100	-

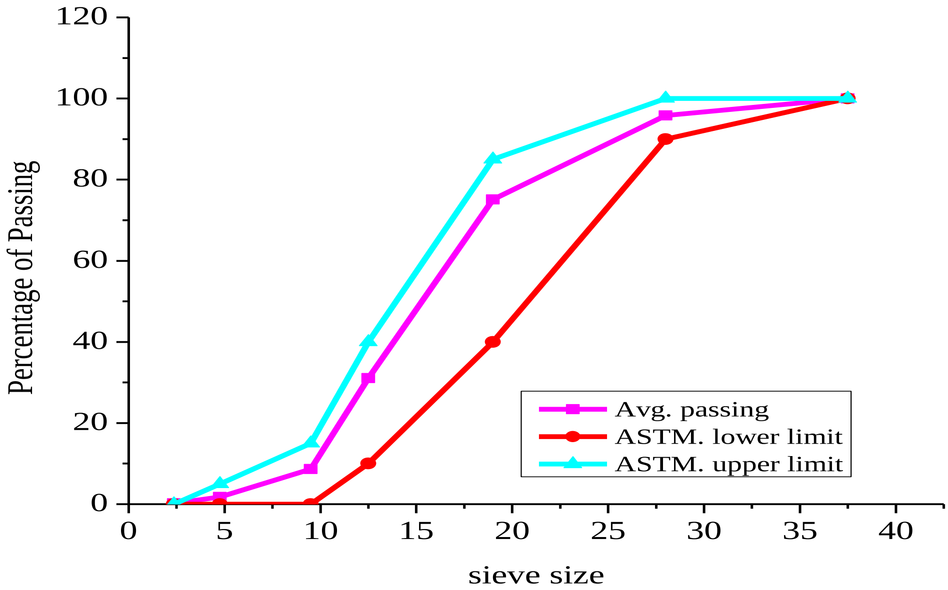


Figure 4-2:Particle size distribution curve for ceramic waste

For sieve analysis of fine aggregate, the fine aggregate used in this study passed the 9.5mm and almost passed $4.75mm$ sieve size which fulfills the standard requirement according to ASTM standard. The fineness module is among 2.67. According to ASTM C 33 this means it was almost within the ASTM limit. Since the FM of natural sand between 2.6-2.9 its medium sand aggregate and the cumulative percentage passes and retains was within the intervals as shown in table 4.4

Table 4. 4 Sieve analysis for fine aggregate

Sieve size	Mass of Samples retained (gm)		Avg. Mass retained (gm)	% Retained	Cumulative % retained	Cumulative % passing
	S-1	S-2				
9.5mm	0.00	0.00	0.00	0.00	0.00	100
4.75mm	39.5	30	34.75	1.7375	1.7375	98.2625
2.36mm	236.5	214.5	225.5	11.275	13.0125	86.9875
1.18mm	244	234	239	11.95	24.9625	75.0375
600µm	471.5	449	460.25	23.0125	47.975	52.025
300µm	650	692.5	671.25	33.5625	81.5375	18.4625
150 µm	307	326	316.5	15.825	97.3625	2.6375
pan	51.5	54	52.75	2.6375	100	-

Table 4. 5 ASTM upper and lower limit of PSD for fine aggregate

Sieve sizes (mm)	Cumulative % passing		Cumulative % Retained	
	ASTM min	ASTM max	ASTM min	ASTM max
9.5mm	100	100	0	0
4.75mm	95	100	5	0
2.36mm	80	100	20	0
1.18mm	50	85	50	15
600µm	25	60	75	40
300µm	5	30	95	70
150 µm	0	10	100	90
pan	0	0	100	100

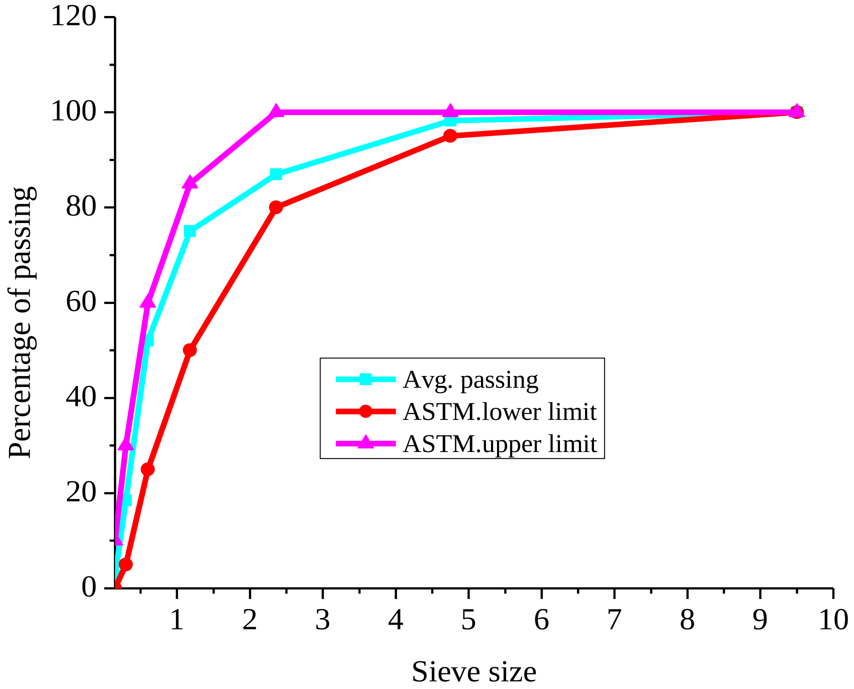


Figure 4- 3: Particle size distribution curve for fine aggregate

The sieve evaluation was done for grinded stone dust which was used as partial replacement of fine aggregate. This was done to determine that the replacing material shows similar particle size distribution with that of natural fine aggregate used. From the test result of sieve analysis, the grinded stone dust shows almost similar behavior to the natural fine aggregate. The Fineness Modulus of grinded stone dust was found to be 2.99. Since the FM is between 2.9-3.2 SD is coarser sand and also confirms to ASTM limits of PSD recommendation as shown in table 4.5.

Table 4. 6 Sieve analysis for stone dust

Sieve size	Mass of Samples retained (gm)		Avg. Mass retained (gm)	% Retained	Cumulative % retained	Cumulative % passing
	S-1	S-2				
9.5mm	0.00	0.00	0.00	0.00	0.00	100
4.75mm	70.5	41	55.75	2.7875	2.7875	98.2125
2.36mm	240	237	238.5	11.925	14.7125	85.2875
1.18mm	402.5	480	441.25	22.0625	36.775	63.225
600µm	445.5	507	476.25	23.8125	60.5875	39.4125

300µm	580.5	508	544.25	27.2125	87.8	12.2
150 µm	224.5	163	193.75	9.6875	97.4875	2.5125
pan	36.5	64	50.25	2.5125	100	-

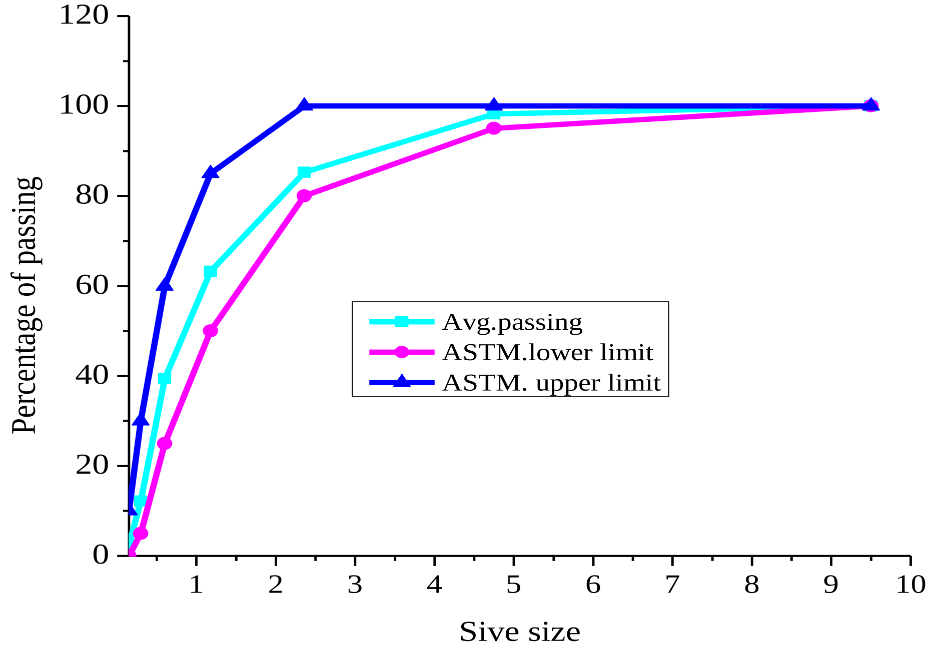


Figure 4-4: Particle size distribution curve for Stone dust

4.2. Effects of ceramic waste and stone dust on concrete tests

Generally, in this research the two main test is conducted testing the properties of fresh concrete and tests on hardened concrete applied in order to investigate the replacement of coarse aggregate by ceramic waste (CW) and fine aggregate by stone dust (SD) in concrete mix. For fresh concrete mix the workability and consistence of the replaced main ingredients by CW and SD in concrete are determined from the slump and compaction factor test method, for hardened concrete, mass density, compressive strength test, split tensile test and flexural beam test are conducted as per the specification.

4.2.1. Workability test of fresh concrete

Workability describes the ease way which a freshly mixed concrete can be laid, transported to a large extent, it was controlled by the amount of water in the concrete. As indicated earlier the slump test and compaction factor test were done on fresh concrete to determine the workability and consistency of concrete. The slump of the concrete is measured through measuring the space from the top of the slumped concrete to the level of the top of the slump cone. In this study slump test was conducted to determine the workability of fresh concrete and consistency of concrete in accordance with ASTM standard.

Table 4. 7:Limits of degree of workability and consistency

Degree of workability	consistency	slump(mm)	Compaction factor
Extremely very low	Moist earth	0	0.65 – 0.70
Very low	Very dry	0 – 25	0.7 – 0.8
Low	Dry	25 – 50	0.8 – 0.85
Medium	Plastic	50 – 100	0.85 – 0.95
High	Semi – fluid	100 – 175	0.95 – 1

Table 4. 8:Slump test result on fresh concrete replacing main ingredient by CW and SD

Designation	Percentage replacement of CW and SD	Slump(mm)	Variation from control (%)
M 00	$0\%\ CW\ and\ 0\%\ SD$	40	-
M 25	$5\%\ CW\ and\ 25\%\ SD$	36	11.11
M 50	$10\%\ CW\ and\ 50\%\ SD$	29	17.77
M 75	$15\%\ CW\ and\ 75\%\ SD$	24	28.89
M 100	$20\%\ CW\ and\ 100\%\ SD$	19	40

From test result it was observed that the replacing of more stone dust and ceramic waste in concrete decreases the value of workability of fresh concrete. From the result of slump test the maximum workability obtained at 0% stone dust and ceramic waste replacement of main ingredients in concrete production. The test result also indicated that for this particular study mix are low and very low workable.

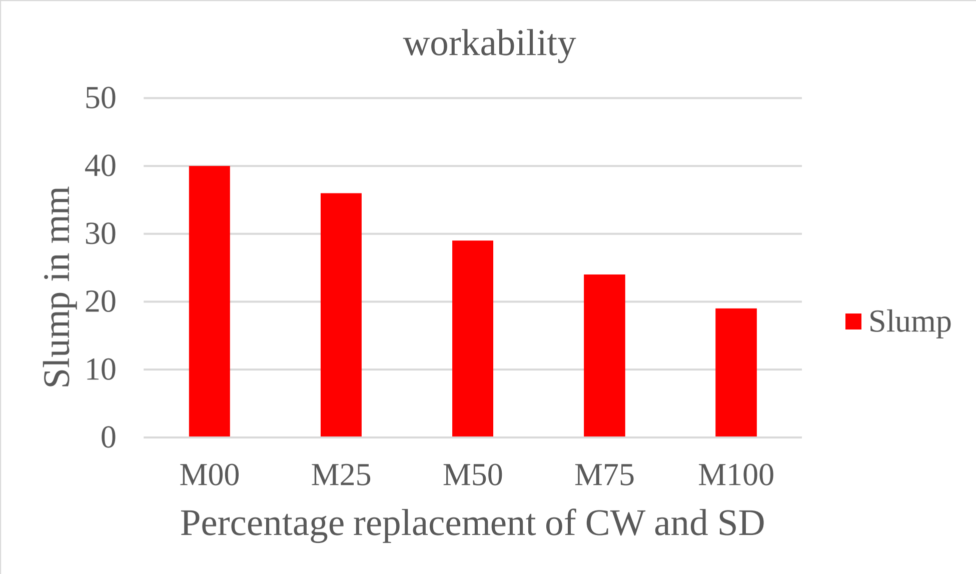


Figure 4- 5: Slump for workability of fresh concrete with replacement of SD and CW

4.2.2. Compaction factor test

Compaction factor test is the workability test for concrete conducted in laboratory. The compaction factor is the ratio of weights of partially compacted to fully compacted concrete. The test is used for concrete which have low workability for which slump test is not suitable. It was taken for each concrete mix for this research. From result shown table 4.9 the degree of consistency of the partially replaced samples are Very dry, dry and plastic. The results compaction factor test is shown in the following table 4.9 and figure 4.6.

Table 4. 9:Compaction factor test result on replacement of SD and CW

Designation	Percentage replacement of CW and SD	Compaction factors	Variation from control (%)
M 00	$0\%\ CW\ and\ \ 0\%\ SD$	0.853	-
M 25	$5\%\ CW\ and\ 25\%\ SD$	0.82	3.87
M 50	$10\%\ CW\ and\ 50\%\ SD$	0.81	5.04
M 75	$15\%\ CW\ and\ 75\%\ SD$	0.77	9.73
M 100	$20\%\ CW\ and\ 100\%\ SD$	0.72	15.59

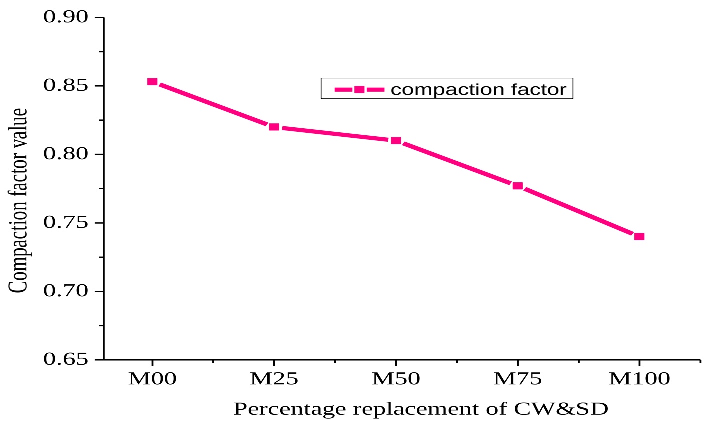


Figure 4-6: Compaction factor of fresh concrete with replacement of SD and CW

From figure 4.6 and figure 4.5, it was clearly observed that, the compaction factor test result and slump test result shows decrease for all percentage addition of SD and CW on concrete as compared to conventional control mix. For the hybrid mix, as the percentage of SD and CW increases the value of both compaction factor and slump was decreased. From slump test it was reduced by 11.11%, 17.77%, 28.89%, and 40% and from compaction factor test it was reduced by 3.87%, 5.04%, 9.73%, and 15.59% for $5\%\,CW - 25\%\,SD$, $10\%\,CW - 50\%\,SD$, $15\%\,CW - 75\%\,SD$, and $20\%\,CW - 100\%\,SD$ addition respectively. For the hybrid ceramic waste and stone dust added to the results of the two test result decreases. This is because of balling formed due to non- uniform distribution of ceramic waste in the concrete mix. In addition, workability test result decreases more as the CW and SD increases in percent in the mix. It can be justified that, the reduction in workability and consistency of reinforced concrete was due to the higher water absorption of stone dust used for mix design as natural sand.

4.3. Mechanical Tests on Hardened Concrete

4.3.1. Mass versus Density of concrete

The variation on the density of concrete specimen studied related with the increase in percentage of replacement main ingredient by ceramic waste and stone dust at 0%, $5\%CW + 25\%\,SD$, $10\%\,CW + 50\%\,SD$, $15\%\,CW + 75\%\,SD$ and $20\%\,CW + 100\%\,SD$ dosage in concrete mix. The result shows that increase in unit weight has been observed in case of cube test specimens containing CW and SD while compared to control conventional concrete specimen. Mass of each individual samples measured and the calculated density of each cube sample is shown in table 4.10.

Table 4. 10 :Mass versus density of the specimen

Cube Unit weight determination at 7 days							
Percent of SD and CW	Mass of cube in (Kg)				Volume in (m^3)	Density in (kg/m^3)	Variation from control in (%)
	S-1	S-2	S-3	Avg.			
Control (0%)	8.425	8.365	8.304	8.36	0.00338	2,477	-
$5\% CW + 25\% SD$	8.42	8.57	8.39	8.46	0.00338	2,506	1.17
$10\% CW + 50\% SD$	8.49	8.32	8.62	8.48	0.00338	2,512	1.41
$15\% CW + 75\% SD$	8.46	8.62	8.477	8.51	0.00338	2,521	1.77
$20\% CW + 100\% SD$	8.57	8.57	8.58	8.57	0.00338	2,540	2.54
Cube Unit weight determination at 14 days							
Percent of SD and CW	Mass of cube in (Kg)				Volume in(m^3)	Density in (kg/m^3)	Reduction in (%)
	S-1	S-2	S-3	Avg.			
Control (0%)	8.225	8.171	8.364	8.29	0.00338	2452	-
$5\% CW + 25\% SD$	8.505	8.49	8.12	8.40	0.00338	2485	1.47
$10\% CW + 50\% SD$	8.44	8.64	8.44	8.53	0.00338	2523	3.1
$15\% CW + 75\% SD$	8.44	8.69	8.52	8.51	0.00338	2517	3.64
$20\% CW + 100\% SD$	8.49	8.59	8.77	8.64	0.00338	2556	4.46
Cube Unit weight determination at 28 days							
Percent of SD and CW	Mass of cube in (Kg)				Volume in(m^3)	Density in (kg/m^3)	Reduction in (%)
	S-1	S-2	S-3	Avg.			
Control (0%)	8.025	7.971	8.164	8.15	0.00338	2411	-
$5\% CW + 25\% SD$	8.305	8.29	8.02	8.17	0.00338	2417	0.25
$10\% CW + 50\% SD$	8.24	8.44	8.24	8.27	0.00338	2446	1.45
$15\% CW + 75\% SD$	8.24	8.49	8.32	8.35	0.00338	2470	2.45
$20\% CW + 100\% SD$	8.29	8.39	8.57	8.42	0.00338	2491	3.33

The unit weight of cube specimens measured at the compressive strength test increases with increasing percentage replacement of SD and CW content in concrete. The increases in unit weight of concrete cube are resulted from the fact that SD has higher density than natural sand aggregate.

4.3.2. Compressive strength test

Compressive strength of concrete performs a critical role in controlling and conforming the quality of cement concrete work. The main factor that governs of the use of concrete in structures is its compressive strength. One of the main properties of the hardened concrete is its strength which the only represents its ability to resist compression loads. The compressive strength of the concrete is considered to be the main important and is often taken as core for the overall quality of concrete. The compressive strength of concrete is the compression load which causes the failure of specimen per unit cross section area of the specimen over which the load is applied.

In this research the effect of partial replacement of CW with coarse aggregates and SD with natural fine aggregate on concrete compressive strength characteristics studied and compared with conventional control specimen. The replacement percentage was $5\% \, CW + 25\% \, SD$, $10\% \, CW + 50\% \, SD$, $15\% \, CW + 75\% \, SD$ and $20\% \, CW + 100\% \, SD$ by weight of coarse and fine aggregate respectively, to compare the compressive strength of partially replaced concrete with the conventional control concrete of C-25 grade concrete. Three independent specimens replaced with the same percentage of CW and SD of cube concrete mix was used at each curing day to determine the compressive strength. The average loads of three specimens are used to calculate the average strength of the cube. All the cubes' specimens were done with the dimension of $150mm \times 150mm \times 150mm$. The result of compressive strength of the cubes tested at the age of 7, 14 and 28 days in compressive testing machine is shown in the table 4.11.

Table 4. 11: Compressive load and the corresponding compressive strength of cube containing CW and SD

7th day compressive strength result							
Code	Percentage replacement	load in KN				Compressive stress in Mpa	Variation from control in %
		S-1	S-2	S-3	Avg.		
M 00	Control	477	407	396	426.67	18.97	-
M 25	$5\% \ CW + 25\% \ SD$	384	371	394	383	17.06	-11.19
M 50	$10\% \ CW + 50\% \ SD$	434	420	406	420	18.65	-1.72
M 75	$15\% \ CW + 75\% \ SD$	362	402	378	380.62	16.91	-12.18
M 100	$20\% \ CW + 100\% \ SD$	405	325	355	361.67	16.07	-18.05
14th day compressive strength result							
Code	Percentage replacement	load in KN				Compressive stress in Mpa	Variation from control in %
		S-1	S-2	S-3	Avg.		
M 00	Control	546.7	568.68	554.2	556.53	24.73	-
M 25	$5\% \ CW + 25\% \ SD$	511.22	457.14	578.83	515.73	22.92	-7.89
M 50	$10\% \ CW + 50\% \ SD$	532.35	510.38	561.08	534.6	23.76	-4.08
M 75	$15\% \ CW + 75\% \ SD$	475.74	454.61	504.46	478.27	21.25	-16.37
M 100	$20\% \ CW + 100\% \ SD$	457.14	455.45	445.31	452.63	20.11	-22.29
28th day compressive strength result							
Code	Percentage replacement	load in KN				Compressive stress in Mpa	Variation from control in %
		S-1	S-2	S-3	Avg.		
M 00	Control	649	675	667.16	663.7	29.5	-
M 25	$5\% \ CW + 25\% \ SD$	607	542	690	613	27.24	-8.29
M 50	$10\% \ CW + 50\% \ SD$	640	615	680	645	28.66	-2.93
M 75	$15\% \ CW + 75\% \ SD$	586	539	654	593	26.35	-11.95
M 100	$20\% \ CW + 100\% \ SD$	560	546	573	559.6	24.87	-18.61

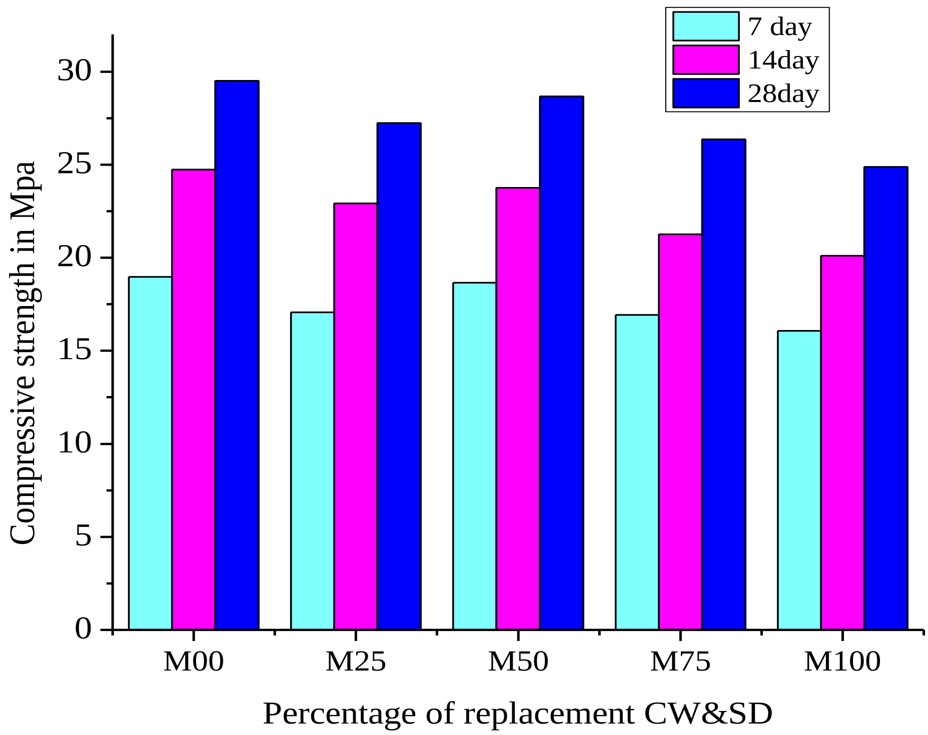


Figure 4-7: Comparison of compressive strength for different percentage of CW & SD replacement

It has been observed from the test result that the cube specimen tested for 7, 14, and 28days with different percentage of SD and CW shows a variation in compressive strength when compared with the control specimen. The reduction in compressive strength of 11.19% ,1.72% ,12.18% and 18.05% observed for $5\%\,CW + 25\%\,SD$, $10\%\,CW + 50\%\,SD$, $15\%\,CW + 75\%\,SD$ and $20\%\,CW + 100\%\,SD$ replacement respectively. It has been also observed from the test results that, at early age of compressive strength test the 7-day strength are satisfactory for C-25 compressive strength as it is greater than 65% of $25\ MPa$ strength for all mix, expect $20\%\,CW + 100\%\,SD$ replacement. At age of 14day concrete test the reduction in compressive strength of 7.89% , 4.08% , 16.37% and 22.29% observed for $5\%\,CW + 25\%\,SD$, $10\%\,CW + 50\%\,SD$, $15\%\,CW + 75\%\,SD$ and $20\%\,CW + 100\%\,SD$ replacement respectively. Similarly, at age of 28-day concrete test, the reduction in compressive strength of 8.29% , 2.93% , 11.95% and 18.61% observed for $5\%\,CW + 25\%\,SD$,$10\%\,CW + 50\%\,SD$,$15\%\,CW + 75\%\,SD$ and $20\%\,CW + 100\%\,SD$ replacement respectively

For the mix with $15\% CW$ & $75\% \ SD$ and $20\% \ CW\$100\%$ of SD partially replaced coarse and fine aggregates the compressive strength goes on decreasing. The reason for the reduction in the compressive strength with the increase in the SD and CW waste may be attributed due to low bonding of CW and SD with other ingredients, as well as the increasing percentage of CW make the concrete flaky.

The 28 days compressive strength of the concrete mixes with $10\% \ CW - 50\% \ SD$ replacement of coarse and fine aggregates respectively shows higher compressive strength than other percentage replacement.

4.3.3. Strain stress relation of cubes containing CW and SD.

In this study the strain stress for cube specimen was analyzed for $0\%, 5\% CW + 25\% SD$, $10\% \ CW + 50\% SD$, $15\% CW + 75\% \ SD$ and $20\% CW + 100\% SD$ partial replacement of fine aggregate with SD and coarse aggregate with CW by weight as concrete mechanical strength improvement for C-25 grade concrete. The strain at peak point of compressive stress was determined by using displacement gauge which was attached on the compressive strength test machine before applying the load to the cube specimen

In this study an attempt was done to draw the stress strain curves from the experimental result of cube test. Indeed, stress is calculated for each respective change in area of cube and respective varying load during the test of compressive strength and strain stress diagram was drawn using the values obtained from the result of computed values for each CW and SD replacement at each curing age of 7-day, 14 day, and 28 days. The nature of the stress-strain diagram was studied based on peak stress and strain at peak stress. The details of all results and values computed for strain stress relation is tabulated in Appendix E.

Table 4. 12: Average compressive stress and strain at peak load for 7 days

7-day stress strain data						
Percentage of CW and SD	Sample	Peak load in (KN)	Compressive stress in (Mpa)	Corresponding strain	Avg. Compressive stress in (Mpa)	Avg. strain
0% (control)	1	477	21.2	0.002	18.97	0.002
	2	407	18.01	0.002		
	3	396	17.6	0.002		
$5\%\ CW + 25\%\ SD$	1	384.0	17.06	0.002	17.06	0.002
	2	371.4	16.51	0.002		
	3	394.7	17.55	0.002		
$10\%\ CW + 50\%\ SD$	1	434	19.289	0.002	18.65	0.002
	2	420	18.67	0.002		
	3	405	18	0.002		
$15\%\ CW + 75\%\ SD$	1	362	16.088	0.002	16.92	0.002
	2	402	17.866	0.002		
	3	378	16.8	0.002		
$20\%\ CW + 100\%\ SD$	1	405	18	0.002	16.07	0.002
	2	325	14.444	0.002		
	3	355	15.777	0.002		

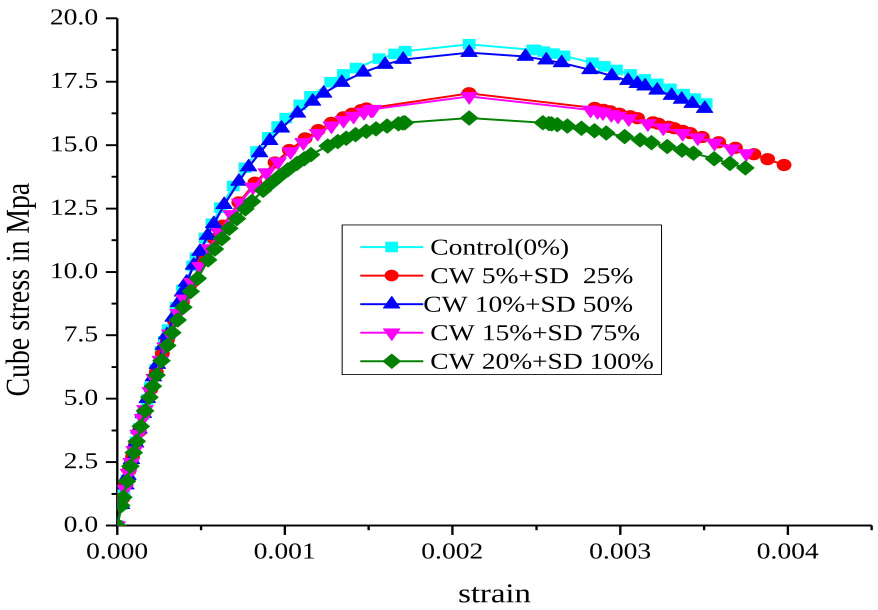


Figure 4-8: The stress - strain responses of concrete cubes at age of 7days

Table 4. 13 :Average compressive stress and strain at peak load for 14 days

14-day stress strain data						
Percentage of CW and SD	Sample	Peak load in (KN)	Compressive stress in (Mpa)	Corresponding strain	Avg. Compressive stress in (Mpa)	Avg. strain
0%	1	546.72	24.30	0.002	24.74	0.002
	2	568.68	25.27	0.002		
	3	554.32	24.64	0.002		
5% CW + 25% SD	1	511.22	22.72	0.002	22.92	0.002
	2	457.14	20.31	0.002		
	3	578.82	25.72	0.002		
10% CW + 50% SD	1	532.35	23.66	0.002	23.76	0.002
	2	510.38	22.68	0.002		
	3	561.08	24.94	0.002		
15% CW + 75% SD	1	481.65	21.41	0.002	21.29	0.002
	2	455.45	20.24	0.002		
	3	500.24	22.23	0.002		
20%CW + 100%SD	1	457.14	20.32	0.002	20.11	0.002
	2	455.45	20.34	0.002		
	3	445.31	19.79	0.002		

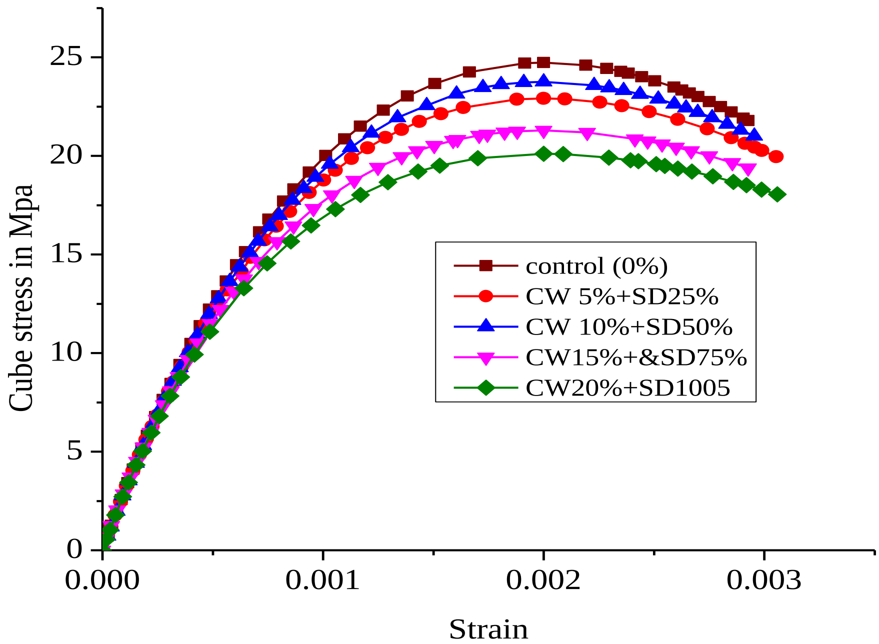


Figure 4- 9: The stress - strain responses of concrete cubes at age of 14 days

Table 4. 14 :Average compressive stress and strain at peak load for 28 days

28-day stress strain data						
Percentage of CW and SD	Sample	Peak load in (KN)	Compressive stress in (Mpa)	Corresponding strain	Avg. Compressive stress in (Mpa)	Avg. strain
0%	1	649	28.84	0.002	29.5	0.002
	2	675	30	0.002		
	3	667.16	29.66	0.002		
$5\%CW + 25\%SD$	1	607	26.97	0.002	27.24	0.002
	2	542	24.089	0.002		
	3	690	30.66	0.002		
$10\%CW + 50\%SD$	1	640	28.444	0.002	28.66	0.002
	2	615	27.33	0.002		
	3	690	30.22	0.002		
$15\%CW + 75\%SD$	1	586	26.04	0.002	26.35	0.002
	2	539	23.95	0.002		
	3	654	26.35	0.002		
20%CW+100%SD	1	560	24.88	0.002	24.87	0.002
	2	546	24.26	0.002		
	3	573	25.46	0.002		

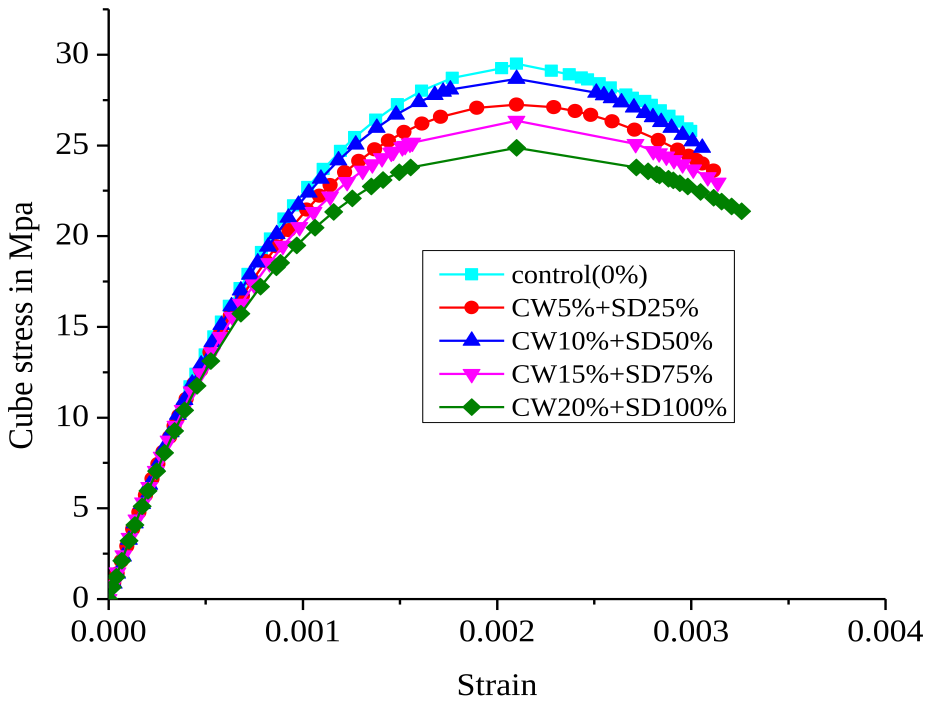


Figure 4- 10: The stress - strain responses of concrete cubes at age of 28 days

From the stress-strain diagram it has been observed that concrete specimens with 15%CW+75%SD and 20%CW+100% SD have comparatively lower compressive strength than that of other percentage replacement. As the stress increases the peak value of the strain decreased. This can be attributed to the decrease in adhesive strength between the surface of both the ceramic waste and stone dust and the cement paste. Additionally, ceramic waste is considered to be a flaky material, so this property may restrict the water necessary for cement hydration during the curing period. It is clearly observed that for concrete mix with 10%CW$50%SD shows related performance to the control. For specimens containing CW and SD after the peak stress the stress decrease at slower rate than the control specimen. This shows the ductile property of SD and CW in preventing more crack than natural aggregate.

Generally, Incorporation of SD as fine aggregate and CW as coarse aggregate in concrete has noticeable influence on the stress- strain curves (SSC) of concrete. Nonetheless, the shape of the stress–strain curve for all the concrete with SD and CW was similar to that of the natural aggregate concrete, regardless of the replacement percentage.

For the 28th days, the modulus of elasticity of CW as coarse aggregate and SD as fine aggregate concrete is varied from 26.47 to 22.89Gpa. That is 1% to 16.7% lower compared to conventional concrete, from M25 to M100 respectively.

4.3.4 Split Tensile Test

Concrete isn't typically predicted to resist the direct tension because of its low tensile strength and brittle nature. Tensile strength is property of concrete which describe tensile crack of concrete due to tensile applied loading. Split Tensile strength of concrete is lower when compared to its compressive strength. Due to difficulty in applying uniaxial tension to a concrete specimen, the tensile strength of concrete may be decided through indirect test method called Split tensile take a look at and it became used on this observe for figuring out tensile residences of concrete specimens.

In these researches, the effect of partial replacement of SD with fine aggregate and CW with coarse aggregates at percentage of $5\%CW + 25\%\,SD, 10\%\,CW + 50\%SD, 15\%CW + 75\%SD$ and $20\,CW\% + 100\%\,SD$ on concrete split Tensile strength studied and compared with control concrete mix. The split tensile strength test result of cylinders at 7,14 and 28days are shown in table 4.15.

Table 4. 15: Split tensile load and the corresponding tensile strength of cylinder containing SD and CW

7^{th} day split tensile test result							
Designation	Percentage of CW and SD	Tensile Load (KN)			Avg. Load (KN)	Split tensile Strength in (Mpa)	Variation from control
		1	2	3			
M 00	$Control$ (0%)	84	80	75	79	2.535	-
M 25	$5\%CW + 25\%SD$	74	72	73	73	2.32	-9.26
M 50	$10\%CW + 50\%SD$	85	75	74	78	2.484	-2.05
M 75	$15\%CW + 75\%SD$	74.23	57.1	85	72.11	2.29	-10.69
M 100	$20\%CW + 100\%SD$	60.5	78	58	65.50	2.09	-21.29
14^{th} day split tensile test result							
Designation	Percentage of CW and SD	Tensile Load (KN)			Avg. Load (KN)	Split tensile Strength in (Mpa)	Variation from control
		1	2	3			
M 00	Control	85.345	105.62	113.23	101.4	3.21	-
M 25	$5\%CW + 25\%SD$	109.85	87.03	85.34	94.04	2.99	-7.35
M 50	$10\%CW + 50\%SD$	108.16	104.78	83.65	98.86	3.14	-2.22
M 75	$15\%CW + 75\%SD$	95.48	81.96	81.12	86.19	2.74	-17.15
M 100	$20\%CW + 100\%SD$	92.95	75.20	85.34	84.5	2.65	-21.13
28^{th} day split tensile test result							
Designation	Percentage of CW and SD	Tensile Load (KN)			Avg. Load (KN)	Split tensile Strength in (Mpa)	Variation from control
		1	2	3			
M 00	Control	101	125	134	120	3.81	-
M 25	$5\%CW + 25\%SD$	130	103	101	111.33	3.54	-7.6
M 50	$10\%CW + 50\%SD$	128	124	99	117	3.72	-2.4
M 75	$15\%CW + 75\%SD$	113	97	96	102	3.25	-17.23
M 100	$20\%CW + 100\%SD$	110	89	101	100	3.18	-19.81

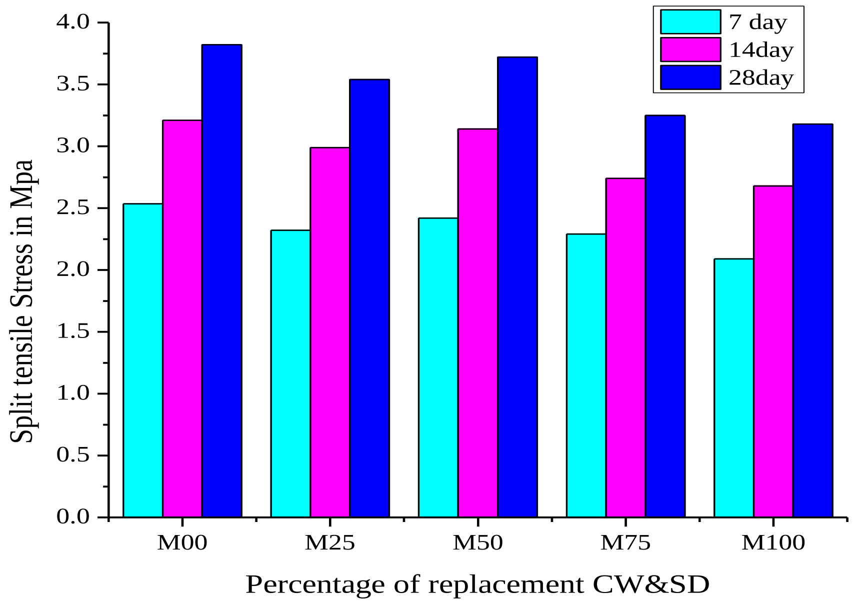


Figure 4- 11: Comparison of split tensile strength for different percentage of CW and SD replacement

From the observed result, it is evident that at the 7day curing age splitting tensile strength values $5\%\ CW + 25\%\ SD$, $10\%\ CW + 50\%\ SD$, $15\%\ CW + 75\%\ SD$ and $20\%\ CW + 100\%\ SD$ replaced concrete specimens were decreased by $9.26\%, 2.05\%, 10.69\%$ and $21.29\ \%$ respectively with respect to control specimen.

Similarly, at the 28day curing age splitting tensile strength values for 5%CW+25%SD, $10\%CW + 50\%SD$, $15\%CW + 75\%SD$ and $20\%CW + 100\%\ SD$ replaced concrete specimens were decreased by $7.6\%, 2.4\%$,17.23% and 19.81% respectively with respect to control specimen.

Thus, the split tensile strength of the concrete mixes affected in terms of tensile strength with the addition of SD as partial replacement of fine aggregate and CW as partial replacement of coarse aggregate in concrete production at 7, 14 and 28days of curing ages. The decreases in split tensile strength are due to low bonding between CW and SD with cement pastes. Also, As the CW increases the flakiness is increases so, flaky material affects the strength of concrete.

4.3.4. Flexural Strength Test Result

Flexural strength gives another way of estimating tensile capacity of concrete. Flexural strength of a concrete is the ability of concrete to with stand without failure of bending stress arise due to applied load on the beam specimen. During pure bending, the member resisting the action is subjected to internal actions or stresses (shear, tensile and compressive). For a bending force implemented downward on a member supported simply at its two ends, fibers above the neutral axis are, generally, subjected to compressive stresses and those below the neutral axis to tensile stresses. For this load and support system, parts of the member near the supports are subjected to relatively higher shear stresses than tensile stresses. In this study, the concrete member to be examined is supported at its ends and loaded at its interior locations by a gradually increasing load to failure. The output of flexural test on concrete expressed as a modulus of rupture.

The test was done to observe the effect of partially replacing fine aggregate and coarse aggregates with SD and CW respectively by different percentage on flexural strength of concrete at 7, 14 and 28days of curing age. The flexural test on concrete conducted using the two points loading and test results on beam specimen at 7day,14day and 28day are shown in table 4.16.

Table 4. 16 :Flexural load and the corresponding flexural strength of beam

7th day Flexural test result							
Designation	Percentage of CW $ SD	Flexural Load (KN)			Avg. Load (KN)	Flexural Strength in (Mpa)	Variation from control
		1	2	3			
M00	$Control$ (0%)	18.6	17.94	17.92	18.05	5.41	-
M25	$5\%CW + 25\%SD$	18.37	13.89	17.16	16.14	4.84	-11.77
M50	$10\%CW + 50\%SD$	18.55	17.85	14.83	17.07	5.12	-5.66
M75	$15\%CW + 75\%SD$	16.32	14.81	15.19	15.44	4.63	-16.84
M100	$20\%CW + 100\%SD$	15.32	14.71	14.19	14.74	4.42	-22.39
14th day Flexural test result							
Designation	Percentage of CW $ SD	Flexural Load (KN)			Avg. Load (KN)	Flexural Strength in (Mpa)	Variation from control
		1	2	3			
M00	$Control$ (0%)	22.46	21.56	20.457	25.43	6.44	-
M25	$5\%CW + 25\%SD$	20.36	19.65	19.61	23.52	5.95	-8.22

M50	$10\%CW + 50\%SD$	21.23	21.49	19.51	24.55	6.21	-3.67
M75	$15\%CW + 75\%SD$	19.40	19.88	18.59	22.83	5.78	-11.38
M100	$20\%CW + 100\%SD$	19.29	17.33	16.74	21.05	5.33	-20.92

28th day Flexural test result

Designation	Percentage of CW $ SD	Flexural Load (KN)			Avg. Load (KN)	Flexural Strength in (Mpa)	Variation from control
		1	2	3			
M 00	$Control$ (0%)	25.58	24.52	23.21	24.43	7.63	-
M 25	$5\%CW + 25\%SD$	23.1	22.26	22.21	22.52	7.05	-8.22
M 50	$10\%CW + 50\%SD$	24.13	24.44	22.1	23.55	7.36	-3.67
M 75	$15\%CW + 75\%SD$	21.97	22.53	21	21.83	6.85	-11.38
M 100	$20\%CW + 100\%SD$	21.83	19.52	18.81	20.05	6.31	-20.92

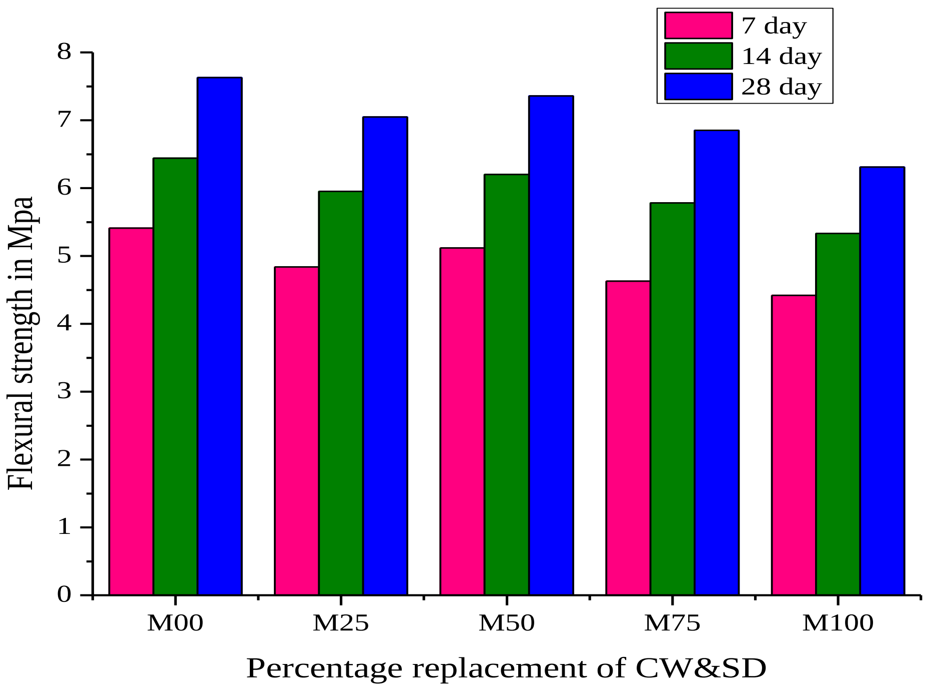


Figure 4- 12: The variation in the flexural strength of the concrete mix with SD and CW

The test result reveals that the performance of beam tested with SD as partial replacement of fine aggregate and CW as coarse aggregates in concrete shows good performance with respect to control concrete mix, expect when fine aggregate is replaced by 20%CW+100% of SD.

Flexural strength of concrete influenced with the addition of CW and SD content in concrete. Replacement of natural fine aggregate with SD and coarse aggregates with CW tends to make concrete ductile and hence increases the ability of concrete to significantly deform before failure. The 28 days flexural strength was found to be maximum for the mixes with 10%CW+50%SD replacement of sand and coarse aggregate (7.36 MPa).

It has been observed from the test results that the mixes with partial replacement of fine aggregates with SD and coarse aggregates with CW waste shows superior performance in the flexural strength compared to the control cement concrete mix. With the increasing of SD and CW in concrete mix beyond 10%CW+50%SD the flexural strength of concrete decreases.

4.4. Optimum Proportion of CW and SD on Concrete Properties

According to laboratory experiment result, the strength used to determine the properties of concrete by addition of different percentage of CW and SD compared to with control group of concrete. From study result, the optimum percentage of CW and SD obtained was 10% and 50% respectively. This optimum percentage addition of CW and SD was recommended depending on all concrete strength compressive, split tensile and flexural strength of concrete for better result.

4.5. Observed failure mode

During testing specimens of replaced with CW and SD concrete samples, failures on cube, flexure, split tensile tests summarized below

A. Failures on cube test

a. Control b. specimen 50% of SD

Figure 4- 13: Failure for control and specimen with partial of SD and CW

As we observation made on this research the addition of ceramic waste and stone dust on concrete mix protects the formation of macro cracks. The macro cracks formation minimized for the all sample of cube tested and the absorbed failure is categorized under satisfactory failure mode.

B. Failures observed on cylinder

It was observed that the addition of ceramic waste and stone dust in concrete mix show small cracks. In general, the crack observed from percentage replacement is decreases as increase the percentage replacement.

Figure 4- 14: Failure Cylinder

It has been observed that under splitting tension load, the conventional test specimen was divided absolutely into two pieces. Little gap was observed at the vicinity of cracked line for concrete sample containing CW and SD at optimum percentage. A little more gap space was found as more CW and SD replace gradients beyond optimum replacement percentage sample and the highest gap in case of 20%CW-100%SD concrete sample. This clearly indicates that CW and SD have capable of crack arresting capacity at optimum dosage CW and SD in concrete.

C. Flexural test

For flexural test failure observed on CW and SD us pull out failure which shows there is minimum bond made between the CW and SD and cement concrete matrix. Also, little breakage of CW and SD observed for 28th day test of flexure.

Figure 4- 15: Crack and failures observed CW and SD beam

All the beam specimen tested under universal testing machine for flexural strength shows vertical crack at the mid span of the beam. Based on this crack the researcher observed that, it is flexural failure. But when crack observed on CW and SD added specimen and plain concrete is compared there is a variation in crack bridging mechanism for each percentage of CW and SD. For control beam it was observed that there is an immediate collapse once the ultimate load is reached such that there is no warning prior to failure.

The crack propagation on plain beam under flexural is very short up to the time of rupture this shows its brittleness more. This corporation improves the ductility of the beam to resist high flexural load. It was observed that as the percentage of CW and SD increases in hybrid mix the flexural strength of the beam decreases.

4.6 Validation of Finite Element Analysis

The load control diagram for the described flexural beam specimens in section 4.3.5 is analyzed by ABAQUS and presented below. The load deflection diagrams are plotted for all percentage replacement of coarse aggregate by CW and fine aggregate by SD with conventional concrete. The beam is plotted in one series separately to compare the effect of replace coarse aggregate within CW and fine aggregate within SD for C-25 grade of concrete.

4.6.1. Load Control

The load deflection of flexural beam concrete from different percentage replacement of coarse aggregate by CW and fine aggregate by SD are plotted below.

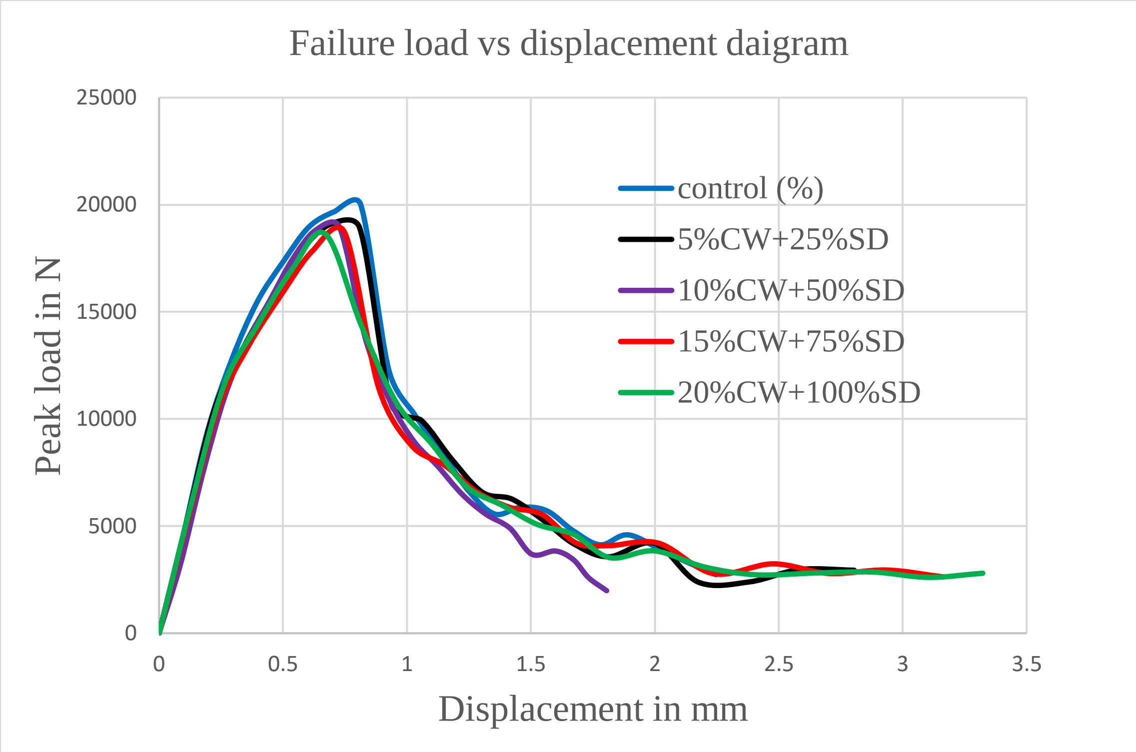
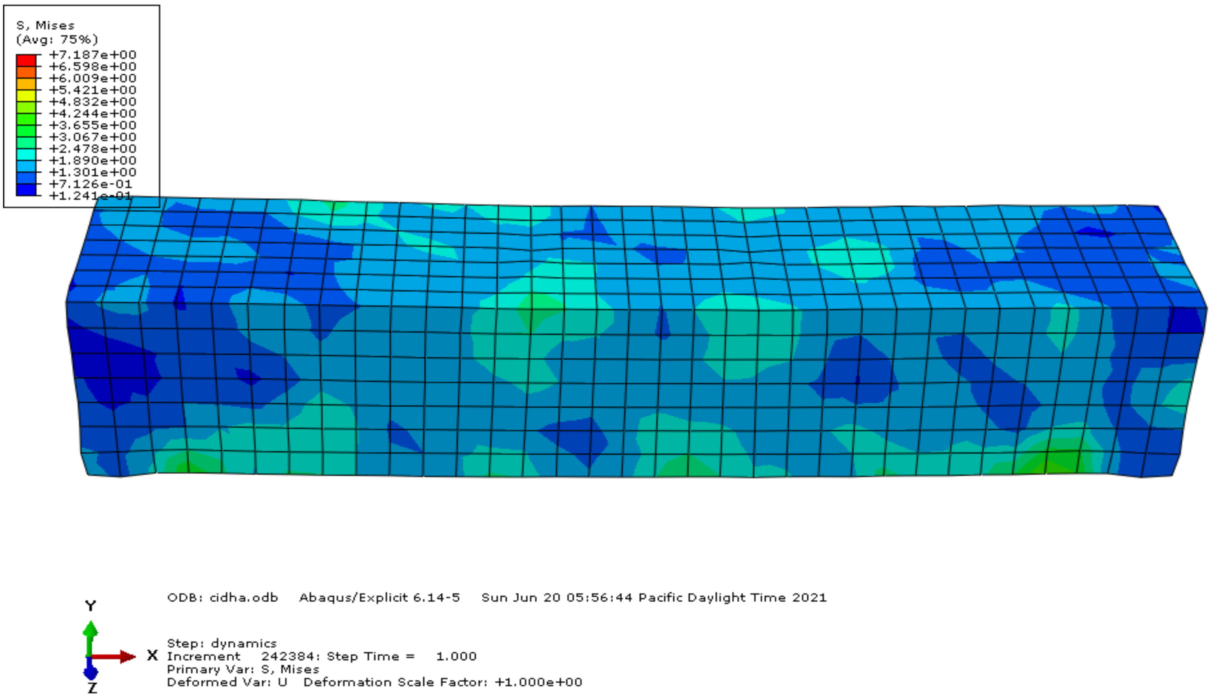


Figure 4-16: Load control diagram for different replacement of CW and SD from ABAQUS

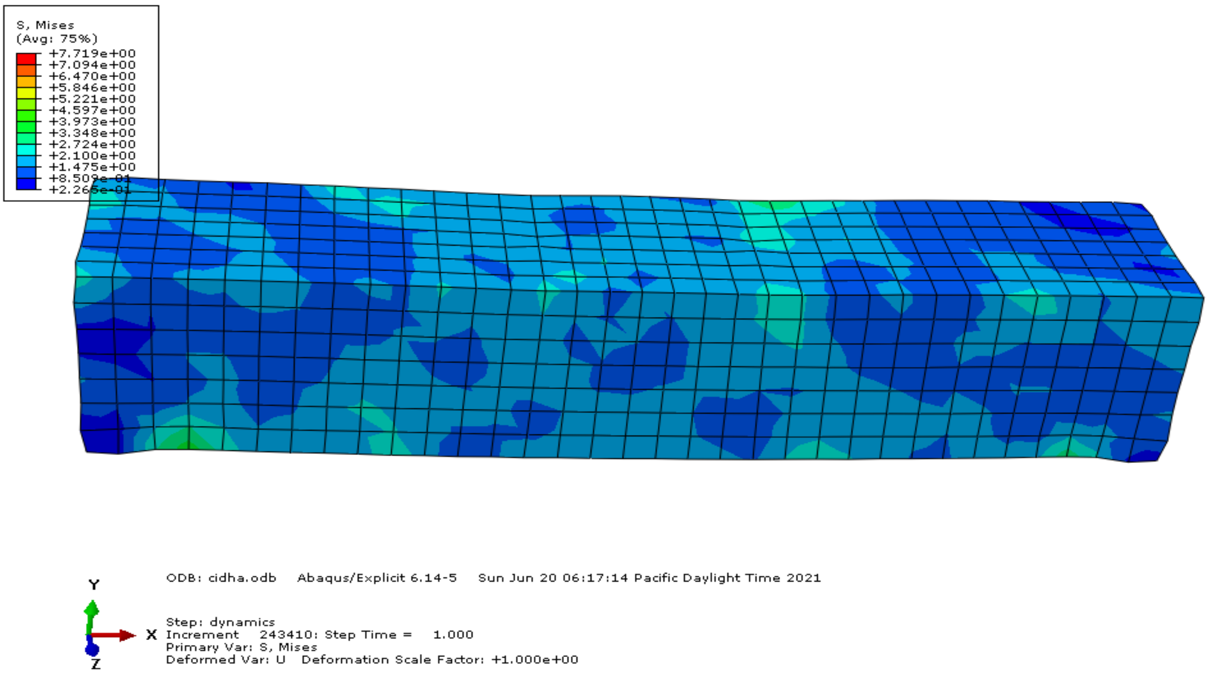
From the fig 4.16 above we observed that the conventional concrete is have greater failure load rather than partial replacement of concrete. From experimental result the failure load of conventional concrete is 24.43KN (from section 4.3.5) but, finite element the failure load is 20.21KN which means finite element load is less than the experiment load, the difference between them is about 9.4% in percentage. From replacement of CW and SD the experimental value of 10%CW+50%SD are having higher load than other replacement, its equal to 23.55KN but the finite element load is 18.97KN, the difference between them are about 10.7% in percentage. In general, the failure load of flexural beam from experiment and finite element are approximately the same.

4.6.2 Stress from Finite element

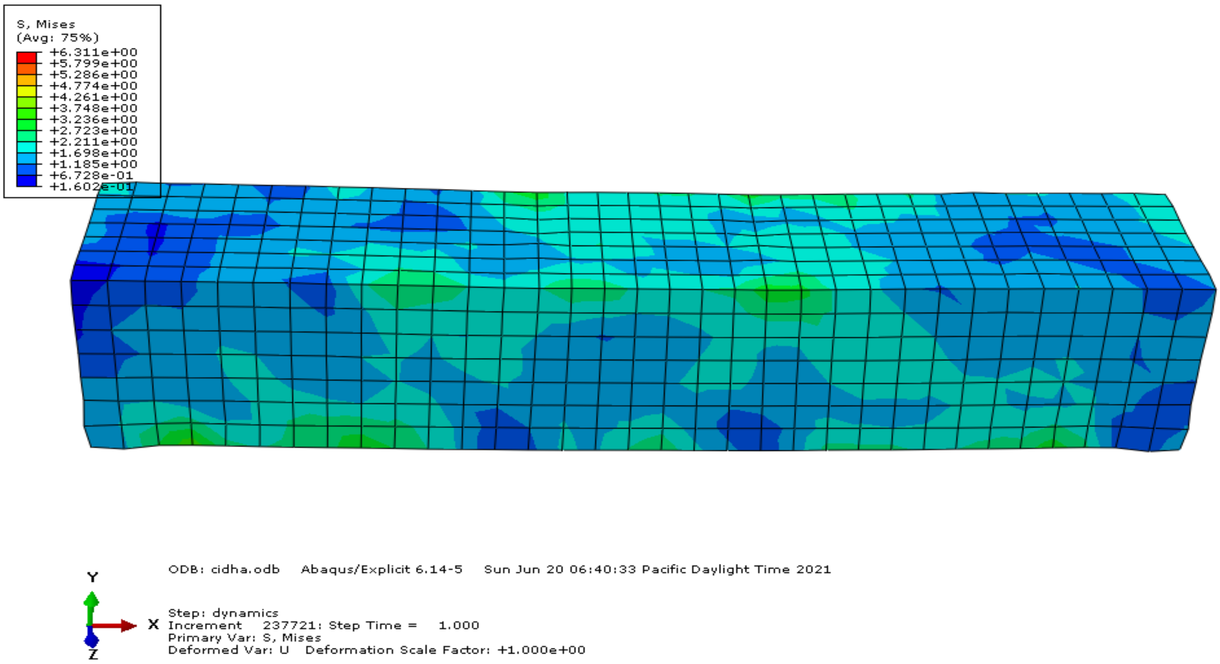
The stress (modulus of rupture) for flexural beam specimens which discussed in section 4.3.5 under table -16 from experiment is analyzed by finite element. The modulus of rupture for all percentage replacement of coarse aggregate by CW and fine aggregate by SD are simulated by finite element method called ABAQUS. The stress analyzed by finite element with the respective value is shown in figure 4.17.



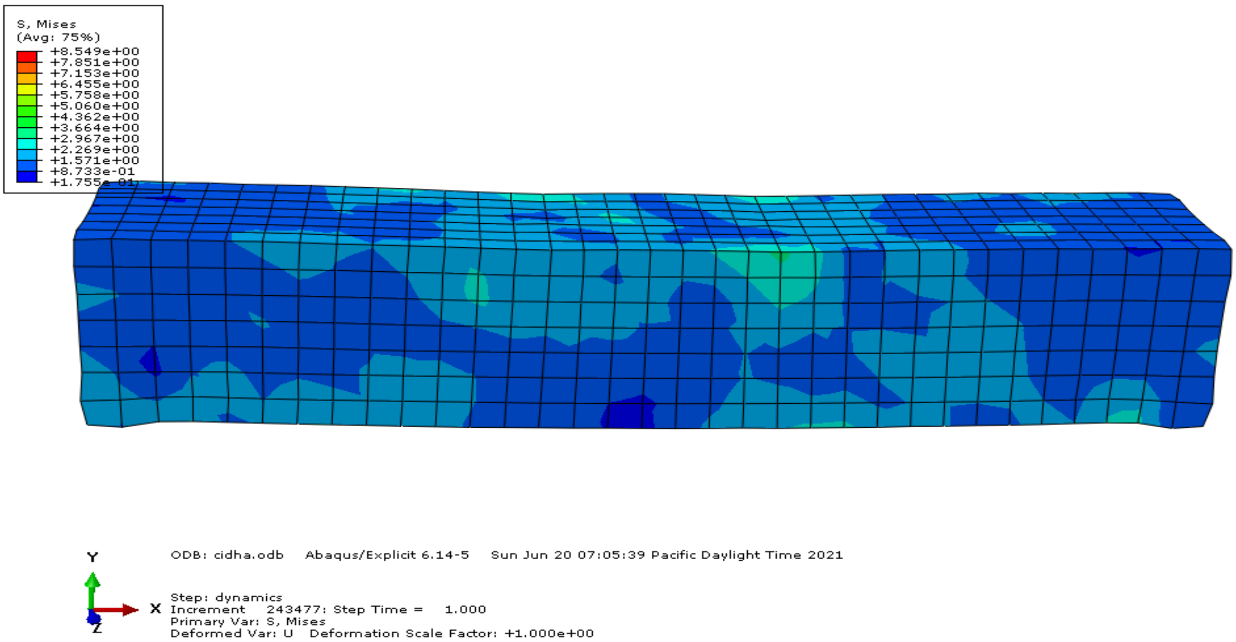
(a) Control (0%)



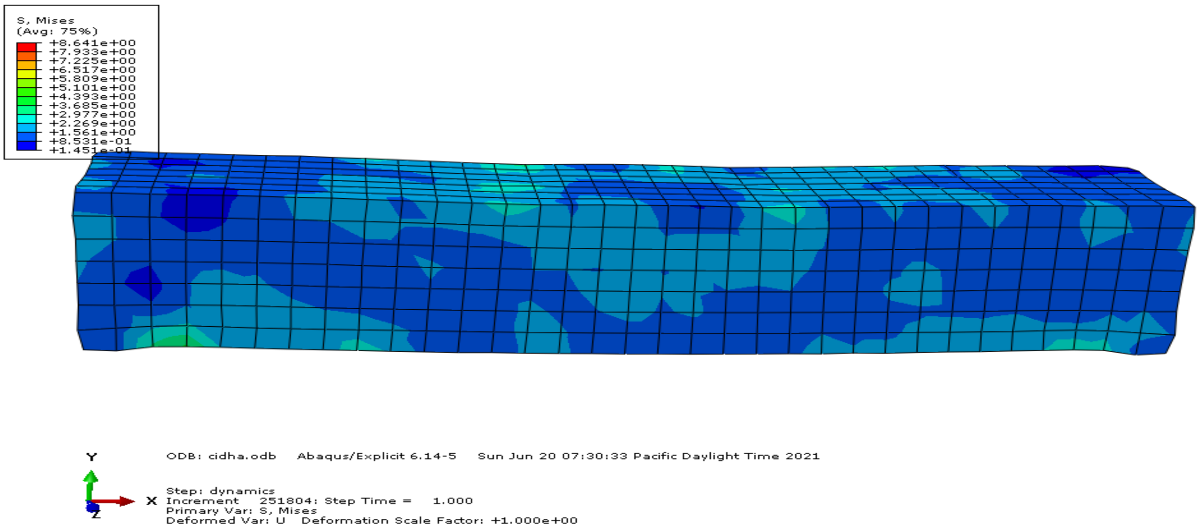
(b) 5%CW+25%SD



(c) 10%CW+ 50SD



(d) 15%CW+75%SD



(e) 20%CW+ 100SD

Figure 4- 17: Finite element result of modulus of rupture and displacement for different replacement of CW and SD

From experimental result the modulus rupture of conventional concrete is 7.63Mpa but, from finite element its equal to 7.19Mpa (from fig 3.6(a)) which means the finite element value is less the experiment value, the difference between them is 2.96% all most they are equal. In general, from FEA the stress at 20%CW+100%SD are larger than other replacement of CW and SD.

4.7 Comparison of experiment and Finite element analysis

4.7.1. Failure load

To show the difference between experiment and finite element analysis the result is drawn on table 4.17 shown below.

Table 4. 17 :Variation of peak load from Experiment and FEA for different replacement

Designation code	% age replacement of CW and SD	Peak load from experiment	Peak load from FEA	Variation from each other in %age
M 00	$Control\ (0\%)$	24.43	20.21	9.4
M 25	$5\%CW + 25\%SD$	22.52	18.93	8.66
M 50	$10\%CW + 50\%SD$	23.55	18.97	10.7
M 75	$15\%CW + 75\%SD$	21.83	18.71	7.6
M 100	$20\%CW + 100\%SD$	20.05	18.64	3.64

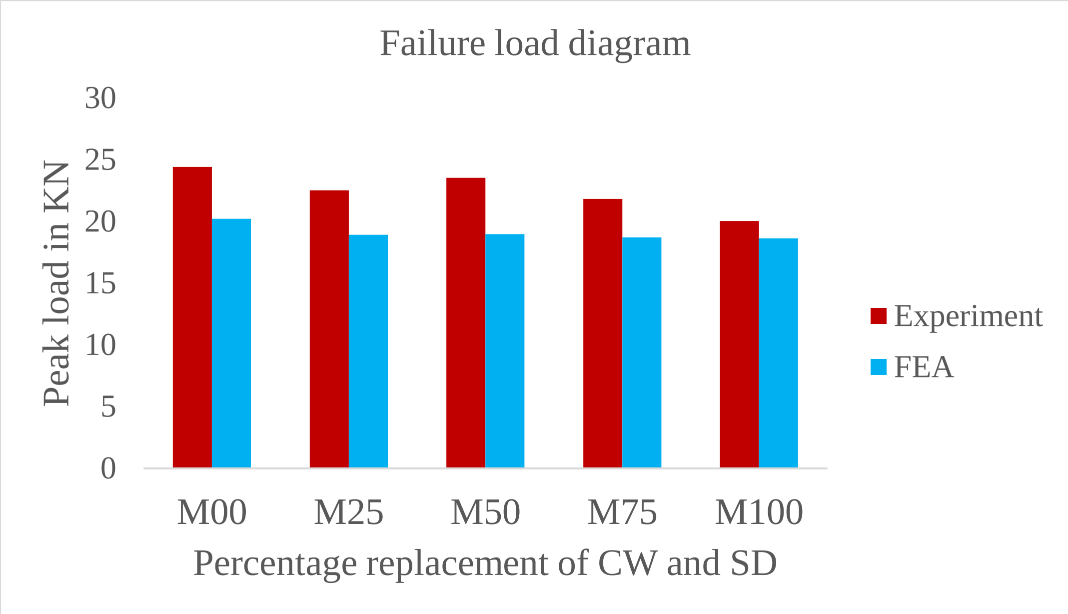


Figure 4-18: Comparison of experimental and FEA on Peak load of concrete

The failure load (peak load) observed from experiment and FEA analysis almost they are similar to each other. From experiment the failure load of the conventional concrete is 24.43KN, the load analyze from FEA is 20.21KN, so the difference between them is about 9.4 in percentage. The other percentage replacement of coarse aggregate by CW and fine aggregate by SD also, *5%CW+25%SD, 10%CW+50%SD, 15%CW+75%SD and 20%CW+100%SD* replacement is varied by *8.66, 10.7, 7.6 and 3.64* respectively.

4.7.2. Stress or Modulus of rupture

To show the difference between experiment and finite element analysis for modulus of rupture the result is drawn on table 4.18 shown below.

Table 4. 18 :Variation of modulus of rupture from experiment and FEA

Designation code	%age replacement of CW and SD	Stress from experiment	Peak load from FEA	Variation from each other in %age
M 00	$Control\ (0\%)$	7.63	7.19	2.97
M 25	$5\%CW + 25\%SD$	7.05	7.71	4.47
M 50	$10\%CW + 50\%SD$	7.36	6.52	6
M 75	$15\%CW + 75\%SD$	6.85	8.54	10.98
M 100	$20\%CW + 100\%SD$	6.31	8.24	12.3

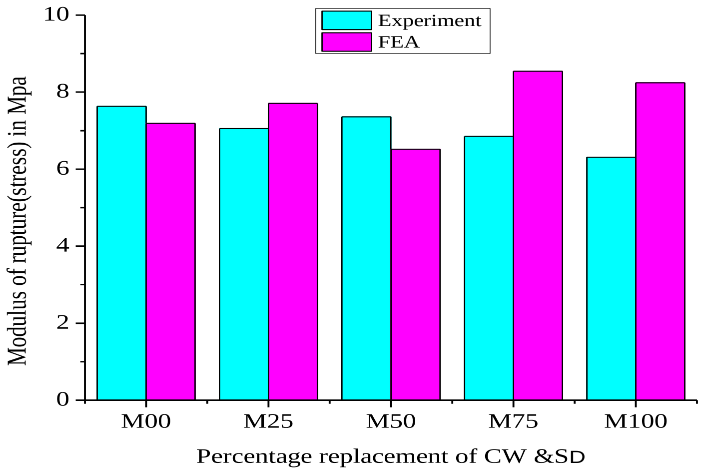


Figure 4- 19: Comparison of experimental and FEA on modulus rupture

The Modulus rupture(stress) obtained from experiment and FEA analysis almost they are similar to each other. From experiment the modulus of rupture of the conventional concrete is 7.63Mpa, the stress analyzed from FEA is 7.19Mpa, so the difference between them is about 2.97 in percentage. The other percentage replacement of coarse aggregate by CW and fine aggregate by SD also, 5%CW+25%SD, 10%CW+50%SD, 15%CW+75%SD and 20%CW+100%SD replacement is varied by 4.47, 6, 10.98 and 12.3 respectively.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

A study was conducted to investigate the possibility of partially replacing naturally available fine aggregate with stone dust and coarse aggregate with ceramic waste in concrete production. The study is aimed at studying the strength characteristics and workability of concrete with partial replacement of natural fine aggregate by stone dust and coarse aggregate by ceramic waste aggregate. Based on the result observed from experiment done on concrete strength with partial replacement of sand with stone dust and coarse aggregate with ceramic waste, the following conclusion was drawn

1. It is identified that waste stone dust and ceramic waste can be used as partial replacement of fine aggregate and coarse aggregate respectively for concrete production in construction industries, except the one which replaced 20% of ceramic waste aggregate and 100% of stone dust aggregate.
2. The density of concrete increases with the increases of stone dust and ceramic waste in concrete, because the unit weight of stone dust is greater than the natural sand.
3. The property of fresh concrete is affected by the addition of stone dust and ceramic waste. With the increase of stone dust and ceramic waste in concrete production the workability of fresh concrete goes on decreasing, because CW and SD are more water absorption than natural aggregates.
4. The mechanical properties of hardened concrete are affected in the partial replacement of fine aggregate with stone dust and coarse aggregate with ceramic waste in concrete. Strength characteristics of concrete decreases with increasing of waste stone dust and ceramic waste. The strength of concrete decreased due to ceramic waste is higher flakiness value, weaker bonding of CW and SD the aggregate with cement pastes due to porcelain surface and higher water absorption of the CW and SD aggregate. Hence, the substitution of coarse aggregate with ceramic waste and Stone dust beyond the 15% CW and 75% SD replacement level is not recommended for use in concrete.
5. The optimum partial replacement of fine aggregate with stone dust and coarse aggregate with ceramic waste in concrete production in terms strength is found to be 50% and 10% respectively.

6. Incorporation of SD as fine aggregate and CW as coarse aggregate in concrete has noticeable influence on the stress- strain curves (SSC) of concrete. Nonetheless, the shape of the stress–strain curve for all the concrete with SD fine aggregate and CW coarse aggregate was similar to that of the natural aggregate concrete, regardless of the replacement percentage. From stress-strain diagram we observed that from 28day, strains were higher for $20\%\ CW + 100\%\ SD$ replacement than for 0% replacement. The grading properties and the fines content of SD and CW may have contributed to the characteristics of stress-strain curve of concrete. The maximum strains for $20\% CW + 100\%\ SD$ replaced aggregate concrete is about 8.7% higher than those of 0% replacement. The main cause of the increase in the peak strain is lower modulus of elasticity, which causes the concrete to undergo larger deformation. For the 28th days, the modulus of elasticity of CW as coarse aggregate and SD as fine aggregate concrete is varied from 26.47 to 22.89Gpa. That is 1% to 16.7% lower compared to conventional concrete, from M25 to M100 respectively.
7. In FEA, the model taken into consideration the nonlinear properties for concrete. The numerical results proposed from the FE model then compared with the experiment data to have a good verification. The result showed that the predicated peak loads and modulus of rupture(stress) of the flexural concrete beam by the present FE models were found to be agrees well with the experimental data. From experimental result the load failure of M00 specimens is 24.43KN, also load failure from the FEA of ABAQUS is 20.21KN, which means the difference between the experiment and analytical simulation are 9.4%, almost similar.

5.2. Recommendation

The effect of CW and SD on concrete mechanical characteristics with partial replacement of coarse and fine aggregate respectively, at various percentages (0%, 5%CW+25%SD, 10%CW+50%SD, 15%CW%+75% SD and 20% CW+100%SD) in concrete production was observed in the study. From the result of test the partial replacement of CW and SD can be used as structural concrete for low load carrying structure such as retaining wall, masonry, ditch and etc. except the one which replaced by 20%CW as coarse and 100%SD as fine aggregates

The present study can be extended for further study to;

1. The test can be carried out to investigate the effect of grades of concrete on mechanical properties of concrete with CW and SD in concrete mix.
2. The use of admixtures in the test can be performed to get improve strength and workability.
3. The study can be extended for shear strength characteristics of concrete with partial replacement of fine aggregate with sone dust and coarse aggregate with ceramic waste in concrete.
4. The durability and shrinkage of concrete with CW and SD has to be tested for beams and columns with varying proportions of ceramic waste and stone dust at different ages.
5. In this study compressive strength and split tensile strength of concrete which replaced by different percentage of ceramic waste and stone dust are conducted by experiment, the future study will analysis this strength by FEA.

Limitation during study

To determine the stress-strain is very difficult because there is no strain gauge to determine stress strain correct manner. The stress strain in this research is conducted by dailgauge with an interval of 5mm and the strain is obtained by change in length by original length. After the strain is determined by dail gauge its normalized by the ES EN 1992-1-1:2015 (section 3.1.5). If strain gauge available the stress strain is easily determined.

REFERENCES

[1] Paul, Bikram .et.al, "Mechanical properties and microstructural features using stone dust as a partial replacement of sand," *International Journal of Engineering and Advanced Technology,* vol. 8, no. 6, pp. 5232-5237, 2019.

[2] Sudharsan, A and Balamurugan, G, "Experimental Investigation on Recycle Plastic in Concrete," pp. 8310-8315, 2017.

[3] Senthamarai, R. M. et.al, "Concrete with ceramic waste aggregate," *Cement and Concrete Composites,* vol. 27, no. 9-10, pp. 910-913, 2005.

[4] Albano, C. et.al, "Influence of content and particle size of waste pet bottles on concrete behavior at different w/c ratios," *Waste Management,* vol. 29, no. 10, pp. 2707-2716, 2009.

[5] T.Subramani, B.Suresh, "Waste As A Coarse Aggregate Making A Light Weight Concrete," *Ijaiem,* vol. 4, no. 5, pp. 153-162, 2015.

[6] Mustafa, Mohd, et.al, "Concrete with ceramic waste and quarry dust aggregates," in *5th ANNUAL CONFERENCE MANAGEMENT IN CONSTRUCTION RESEARCHERS ASSOCIATION*, 2006.

[7] Kare, Sridhar, et.al, "mpact of Construction Material on Environment-(Steel & Concrete)," no. 1, p. 66, 2009.

[8] Lore-lca, E U, et.al, "Reducing the environmental impact of building materials," *Environment,* no. 232, pp. 1-2, 2011.

[9] P. M. Nemati, "CM 425,Concrete Technology," *Winter Quarter,university of Washington, USA.*, 2015.

[10] D. Addissie, "Handling of Concrete Making Materials in the Ethiopian Construction Industry," no. October, p. 184, 2005.

[11] Knepper, W.H. Langer & D.H.Knepper, "Geological characterization of natural aggregates.," 1995.

[12] A. Dinku, "the Need for Standardization of Aggregates for Concrete Production in Ethiopian Construction," pp. 1-15, 2005.

[13] ACI Committee E-701, "Aggregates for Concrete," *ACI Education Bulletin E1-07 (2007),*, pp. 1-26, 2007.

[14] R. Documents, "]ASTM C 127– 88 (Standard Test Method for Specific Gravity and Absorption ofCoarse Aggregate," vol. 91, pp. 1-9, 2007.

[15] Ngugi, Hannah Nyambara.et.al, "Effects of Sand Quality on Compressive Strength of Concrete: A Case of Nairobi County and Its Environs, Kenya," *pen Journal of Civil Engineering,* no. 03, pp. 255-273, 2014.

[16] Rached, Marc. et.al, "Utilizing Aggregates Characteristics to Minimize Cement Content in Portland Cement Concrete," *International Center for Aggregate Research,* no. 401, pp. 179-189, 2009.

[17] Pacheco-Torgal, Fernando. et.al, "Compressive strength and durability properties of ceramic wastes based concrete," *Materials and Structures/Materiaux et Constructions,* vol. 44, no. 1, pp. 155-167, 2011.

[18] K. Ramadevi, "A study on properties of concrete with ceramic waste replaced for fine aggregate," *nternational Journal of Civil Engineering and Technology,* vol. 8, no. 8, pp. 1730-1737, 2017.

[19] Steven H. Kosmatka,et.al, Design and Control Design and Control of mixtures, 2008, p. 32.

[20] Woldegiorgis., YohannesF, "Economic and Environmental Impacts of Plastic Waste: a Case Study in Addis Ababa City, Ethiopia.," *International Journal of Advanced Research,* vol. 5, no. 6, pp. 1624-1630, 2017.

[21] Bazaz, Jb , et .al, "Performance of concrete produced with crushed bricks as the coarse and fine aggregate," *The 10th IAEG International Congress,* no. 616, pp. 1-10, 2006.

[22] Juan, Andrés, et.al, "Re-Use of ceramic wastes in construction," *Recycling: Processes, Costs and Benefits,* pp. 271-284, 2011.

[23] Singh, Amit Kumar ,et.al, "Stone Dust in Concrete : Effect on Compressive Strength," vol. 0869, no. 8, pp. 115-118, 2015.

[24] Kumar, A. Vinodh,et.al, "An experimental investigation on strength properties of concrete by partial replacement of cement with fly ash and fine aggregate with stone dust," *International Journal of Engineering and Advanced Technology,* vol. 8, no. 2, pp. 87-89, 2019.

[25] Kumar Suman, Brajesh, et .al, "Utilization of Stone Dust as Fine Aggregate Replacement in Concrete," *ournal of Multidisciplinary Engineering Science and Technology (JMEST),* vol. 2, no. 4, pp. 704-708, 2015.

[26] Kankam, Charles K.et.al, "Stress-strain characteristics of concrete containing quarry rock dust as partial replacement of sand," *Case Studies in Construction Materials,* vol. 7, no. June, pp. 66-72, 2017.

[27] Singh, Utpal, et .al, "Study on Properties of Concrete (M40) Using Stone Dust and Demolished Concrete Waste As Partial Replacement of Fine and Coarse Aggregate : a Review," pp. 492-495, 2018.

[28] Manimaran, A.Somasundaram, et. al, "Experimental study on partial replacement of coarse aggregate by bamboo and fine aggregate by quarry dust in concrete," *International Journal of Civil Engineering and Technology,* vol. 8, no. 8, pp. 1019-1027, 2017.

[29] Hafezolghorani, Milad et al., "Simplified damage plasticity model for concrete," *Structural Engineering International,* vol. 27, no. 1, pp. 68-78, 2017.

[30] A. Dinku, Construction Materials labratory manual, addis ababa : Addis Ababa University Instituteof Technology, 2002.

[31] Report, State-of-the-art, Production and utilisation of molasses, vol. 82, S. W. D. Børge Johannes Wigum, Ed., 2009, p. 264.

[32] Tavakoli, D et.al, "PROPERTIES OF CONCRETES PRODUCED WITH WASTE CERAMIC TILE AGGREGATE," *ASIAN JOURNAL OF CIVIL ENGINEERING (BHRC),* vol. 14, no. 3, pp. 369-382, 2013.

ANNEX

A: MATERIALS TEST RESULT

A.1. Properties of cement

A.1.1. Normal consistency of Dangote PPC

Test no	Sample weight [gm]	Water added [gm]	% Of Water	Penetration [mm]
1	400	120	30	5
2	400	128	32	8
3	400	132	33	9

A.2.PropertiesofFineAggregate

A.2.1. Silt content

Chaweqa river sand was used for the sample of research test

Formula;

$$\textbf{Silt content}\ \%\ (\mathbf{A}) = \frac{B-C}{B} \times 100 \qquad Equ.1A$$

Where:

$A =$ percentage of material that is finer than 75µm (#200) sieve size

$B =$ Original dry mass before wash in gram =1000gm

$C =$ Dry mass of sample after washed in gram =965gm

Laboratory result

$$\textbf{Silt content}\ \%\ (\mathbf{A}) = \frac{B-C}{B} \times 100 = \left(\frac{1000-965}{1000}\right) \times 100 = 3.5\%$$

it is acceptable according to

Stone dust silt determination before washing

$B = 1000g\ , \qquad C = 924g$

$$\textbf{Silt content}\ \%\ (\mathbf{A}) = \frac{B-C}{B} \times 100 = \left(\frac{1000-924}{1000}\right) \times 100 = 7.6\%$$

Stone dust silt determination after washed

$$B = 1000g \;,\quad C = 989.5g$$

$$\textbf{Silt content}\ \%\ (\mathbf{A}) = \frac{B - C}{B} \times 100 = \left(\frac{1000 - 989.5}{1000}\right) \times 100 = 1.1\%$$

A.2.2. Sieve Analysis

A.2.2.1. Sieve analysis Fine Aggregate

Table 1A: Sieve Analysis of Fine Aggregate Chaweqa sand

Sieve size	Mass of Samples retained (g)		Avg. Mass retained (g)	% Retained	Cumulative % retained	Cumulative % passing
	S-1	S-2				
9.5mm	0.00	0.00	0.00	0.00	0.00	100
4.75mm	39.5	30	34.75	1.7375	1.7375	98.2625
2.36mm	236.5	214.5	225.5	11.275	13.0125	86.9875
1.18mm	244	234	239	11.95	24.9625	75.0375
600µm	471.5	449	460.25	23.0125	47.975	52.025
300µm	650	692.5	671.25	33.5625	81.5375	18.4625
150 µm	307	326	316.5	15.825	97.3625	2.6375
pan	51.5	54	52.75	2.6375	100	-

$$Fineness\ Modulus\ = \frac{\sum Cumulative\ retained}{100} = \frac{266.6}{100} = 2.67$$

Table 2A: Sieve Analysis of Fine Aggregate Stone dust

Sieve size	Mass of Samples retained (g)		Avg. Mass retained (g)	% Retained	Cumulative % retained	Cumulative % passing
	S-1	S-2				
9.5mm	0.00	0.00	0.00	0.00	0.00	100
4.75mm	70.5	41	55.75	2.7875	2.7875	98.2125
2.36mm	240	237	238.5	11.925	14.7125	85.2875
1.18mm	402.5	480	441.25	22.0625	36.775	63.225
600µm	445.5	507	476.25	23.8125	60.5875	39.4125
300µm	580.5	508	544.25	27.2125	87.8	12.2
150 µm	224.5	163	193.75	9.6875	97.4875	2.5125
Pan	36.5	64	50.25	2.5125	100	-

$$Fineness\ Modulus\ =\frac{\sum Cumulative\ retained}{100}=\frac{299.15}{100}=2.99$$

A.2.2. Specific gravity of Chaweka river sand

Specific gravity determination of sample 1

Where: A= mass of oven dry sample in air = 494.5g

B =mass pycnometer +water = 1560g

C=mass sample + pycnometer+ water =1854.2g

D= mass sample = 500g

Bulk specific gravity

$$Bulk\ specific\ gravity=\frac{A}{B+D-C}=\frac{494.5}{560+500-1854.2}=2.403$$

Bulk specific gravity (saturated surface dry)

$$Bulk\ specific\ gravity\ (SSD)=\ \frac{D}{B+D-C}=\frac{500}{1560+500-1854.2}=2.43$$

Apparent specific gravity

$$Apparent\ specific\ gravity\ (SSD)=\ \frac{A}{B+A-C}=\frac{494.5}{1560+494.5-1854.2}$$

$$=2.47$$

Absorption capacity

$$Absorption\ (\%)=\ \frac{500-A}{A}*100=\left(\frac{500-494.5}{494.5}\right)*100=1.11$$

Specific gravity determination of sample 2

Where: A= mass of oven dry sample in air = 493.5g

B =mass pycnometer +water = 1560g

C=mass sample + pycnometer+ water =1855.8g

D= mass sample = 500g

Bulk specific gravity

$$Bulk\ specific\ gravity\ = \frac{A}{B+D-C} = \frac{493.5}{1560+500-1854.2} = 2.42$$

Bulk specific gravity (saturated surface dry)

$$Bulk\ specific\ gravity\ (SSD) = \frac{D}{B+D-C} = \frac{500}{1560+500-1855.8} = 2.45$$

Apparent specific gravity

$$Apparent\ specific\ gravity\ (SSD) = \frac{A}{B+A-C} = \frac{493.5}{1560+494.5-1855.8}$$

$$= 2.47$$

Absorption capacity

$$Absorption\ (\%) = \frac{500-A}{A} * 100 = \left(\frac{500-493.5}{493.5}\right) * 100 = 1.317$$

Table 3A: summary of Specific gravity of Chaweqa sand

Sample	C(g)	B(g)	A(g)	Bulk spe. Gravity	Bulk spe. Gravity(SSD)	Apparent sp.gavity	Absoption (%)
1	1854.2	1560	494.5	2.403	2.43	2.47	1.11
2	1855.8	1560	493.5	2.42	2.45	2.47	1.317
Average				2.41	2.44	2.47	1.21

A.2.3. Specific gravity of stone dust

Specific gravity determination of sample 1

Where: A= mass of oven dry sample in air = 494.5g

B =mass pycnometer +water = 1560g

C=mass sample + pycnometer+ water =1873g

D= mass sample = 500g

Bulk specific gravity

$$Bulk\ specific\ gravity\ = \frac{A}{B+D-C} = \frac{493}{1560+500-1873} = 2.64$$

Bulk specific gravity (saturated surface dry)

$$Bulk\ specific\ gravity\ (SSD) = \frac{D}{B+D-C} = \frac{500}{1560+500-1873} = 2.67$$

Apparent specific gravity

$$Apparent\ specific\ gravity\ (SSD) = \frac{A}{B+A-C} = \frac{494.5}{1560+494.5-1873}$$

$$= 2.72$$

Absorption capacity

$$Absorption\ (\%) = \frac{500-A}{A} * 100 = \left(\frac{500-494.5}{494.5}\right) * 100 = 1.11$$

Specific gravity determination of sample 2

Where: A= mass of oven dry sample in air = 493.5g

B =mass pycnometer +water = 1560g

C=mass sample + pycnometer+ water =1865g

D= mass sample = 500g

Bulk specific gravity

$$Bulk\ specific\ gravity = \frac{A}{B+D-C} = \frac{493.5}{1560+500-1865} = 2.60$$

Bulk specific gravity (saturated surface dry)

$$Bulk\ specific\ gravity\ (SSD) = \frac{D}{B+D-C} = \frac{500}{1560+500-1865} = 2.56$$

Apparent specific gravity

$$Apparent\ specific\ gravity\ (SSD) = \frac{A}{B+A-C} = \frac{493.5}{1560+494.5-1865}$$

$$= 2.62$$

Absorption capacity

$$Absorption\ (\%) = \frac{500 - A}{A} * 100 = \left(\frac{500 - 493.5}{493.5}\right) * 100 = 1.317$$

Table 4A: summary of Specific gravity of Stone dust sand

sample	C(g)	B(g)	A(g)	Bulk spe. Gravity	Bulk spe. Gravity(SSD)	Apparent sp.gavity	Absoption (%)
1	1854.2	1560	494.5	2.64	2.67	2.72	1.11
2	1855.8	1560	493.5	2.6	2.56	2.62	1.317
Average				2.62	2.615	2.67	1.214

A.2.4. Moisture content of Chaweka river sand

Moisture content determination of sample 1

A = weight of original sample = 500g
B= weight of oven dry sample = 496.5g
W= moisture content (%)

Moisture (%) = $\frac{A-B}{B} * 100 = \frac{500-496.5}{496.5} * 100$ = 0.705

Moisture content determination of sample 2

A = weight of original sample = 500g

B= weight of oven dry sample = 497.5g

W= moisture content (%)

$$Moisture\ (\%) = \frac{A - B}{B} * 100 = \left(\frac{500 - 497.5}{497.5}\right) * 100 = 0.5$$

A.2.5. Moisture content of stone dust

Moisture content determination of sample

A = weight of original sample = 500g

B= weight of oven dry sample = 495g

W= moisture content (%)

$$Moisture\ (\%) = \frac{A - B}{B} * 100 = \left(\frac{500 - 495}{495}\right) * 100 = 1.01$$

A.3. Properties Coarse aggregate

A.3.1. Sieve analysis Coarse aggregate

I) Crushed Basaltic stone coarse aggregate sieve analysis

Table 5A: Sieve analysis test results of crushed basaltic stone coarse aggregate

Sieve size (mm)	Mass of Samples retained (g)		Avg. Mass retained (g)	% Retained	Cumulative % retained	Cumulative % passing
	s-1	s-2				
37.5	0	0	0	0	0	100
28	410	408	409	4.09	4.09	95.91
19	2353	2289	2321	23.21	27.6	72.4
12.5	4107	4393	4250	42.5	70.1	29.9
9.5	2196	2135	2165.5	21.65	91.75	8.25
4.75	651	459	555	5.55	97.3	2.7
2.36	276	312	274	2.74	99.95	0.05
Pan	7	4	5.5	0.05	100	-

$$Fineness\ Modulus\ = \frac{\sum Cumulative\ retained}{100} = \frac{490}{100} = 4.90$$

Table 6A: Sieve analysis test results of ceramic waste coarse aggregate

Sieve size (mm)	Mass of Samples retained (g)		Avg. Mass retained (g)	% Retained	Cumulative % retained	Cumulative % passing
	s-1	s-2				
37.5	0	0	0	0	0	100
28	171.5	249	210.25	4.205	4.205	95.795
19	1040.5	1031	1035.75	20.715	24.92	75.08
12.5	2162.5	2240	2201.25	44.025	68.945	31.055
9.5	1157.5	1080.5	1119	22.38	91.325	8.675
4.75	355	337	346	6.92	98.245	1.755
2.36	109.5	45	77.25	1.545	99.79	0.21
pan	3.5	17.5	10.5	0.21	100	-

$$Fineness\ Modulus\ = \frac{\sum Cumulative\ retained}{100} = \frac{487}{100} = 4.87$$

A.3.2. Compacted Unit weight of basaltic coarse aggregate

Wt of cylindrical metal(kg)	Wt of container + aggregate (kg)	Height of cylinder (m)	Dia. of cylinder (m)	Wt of aggregate (kg)	Volume of container (m^3)	Compacted unit eight (kg/m^3)
1.677	18.8475	0.3	0.25	17.1705	0.01	**1717.05**

A.3.3. Specific gravity basaltic coarse aggregate

Weight of oven dry sample in air (mass A) = 1985.5g

Weight of saturated surface dry sample in air (mass B) = 2008.9 g

Weight of saturated sample in water (mass C) = 1319.5 g

Bulk specific gravity:

$$\text{Bulk specific gravity (SSD)} = \frac{B}{B-C} = \frac{2008.9}{20008.9-1319.6} = \mathbf{2.41}$$

Absorption capacity

$$\text{Absorption (\%)} = \frac{B-A}{A} * 100$$

$$\text{Absorption } \mathbf{(\%)} = \frac{2008.5-1985.5}{1985.5} * 100 = \mathbf{0.75}$$

A.3.4. Moisture content of basaltic coarse aggregate

A = weight of original sample = 2000g	
B= weight of oven dry sample = 1985.5g	Sample 1
B= weight of oven dry sample = 1985g	Sample 2

Sample1 Moisture (%) = $\frac{A-B}{B} * 100$

Moisture (%)= $\frac{2000-1980}{1980} * 100$ =**1.0%**

Sample 2 Moisture (%) = $\frac{A-B}{B} * 100$

Moisture (%)= $\frac{2000-1985.5}{1985.5} * 100$ =**0.73%**

A.3.2. Compacted Unit weight of ceramic waste coarse aggregate

Wt of cylindrical metal(kg)	Wt of container + aggregate (kg)	Height of cylinder (m)	Dia. of cylinder (m)	Wt of aggregate (kg)	Volume of container (m^3)	Compacted unit eight (kg/m^3)
1.677	16.8966	0.3	0.25	15.2066	0.01	**1520.66**

A.3.3. Specific gravity ceramic waste coarse aggregate

Weight of oven dry sample in air (mass A) = 1999.56g

Weight of saturated surface dry sample in air (mass B) = 2018.35g

Weight of saturated sample in water (mass C) = 1231.5g

Bulk specific gravity:

Bulk specific gravity (SSD)= $\frac{B}{B-C}$= $\frac{2018.5}{2018.5-1231.5}$= **2.565**

Absorption capacity

Absorption (%)= $\frac{B-A}{A}*100$

Absorption **(%)=** $\frac{2018.5-1999.5}{2018.5}*100$ = **0.94%**

A.3.4. Moisture content

A = weight of original sample = 2000g
B= weight of oven dry sample = 1965g
W= moisture content (%)

Moisture (%) = $\frac{A-B}{B}*100$

Moisture (%)= $\frac{2000-1965}{1965}*100$ =**1.79%**

Flakiness Index

Flakiness index is defined as the percentage (by mass) of stones in an aggregate having an average least dimension (ALD) of less than 0.6 times their average dimension. It is determined by: -

FI = $\frac{w}{W}$*100%

Where W= Total weight of the fraction

W= Total weight of passing fraction

Table 7A. Flakiness index determination of coarse aggregate

Control				
Sizes of aggregates		Thickness of gauge (0.6times the mean size of the two sieve sizes (mm)	Weight of the fraction (g)	Weight of the aggregate in each fraction passing(g)
Passing through (mm)	Retained on Sieve (mm)			
37.5	28	13.5	186.5	40.5
28	20	10.8	1190.5	175.5
20	14	8.55	2235.5	326
14	10	6.75	1281.5	12
10	6.3	4.89	467	46
Total			5361	600

For 5%CW replacement				
Sizes of aggregates		Thickness of gauge (0.6times the mean size of the two sieve sizes (mm)	Weight of the fraction (g)	Weight of the aggregate in each fraction passing(g)
Passing through (mm)	Retained on Sieve (mm)			
37.5	28	13.5	181.5	41.5
28	20	10.8	1140.5	191
20	14	8.55	2217.5	351
14	10	6.75	1261.5	192
10	6.3	4.89	405	49
Total			5206	824.5

For 10%CW replacement				
Sizes of aggregates		Thickness of gauge (0.6times the mean size of the two sieve sizes (mm)	Weight of the fraction (g)	Weight of the aggregate in each fraction passing(g)
Passing through (mm)	Retained on Sieve (mm)			
37.5	28	13.5	171.5	52.5
28	20	10.8	1040.5	220
20	14	8.55	2162.5	471
14	10	6.75	1157.5	251
10	6.3	4.89	355	52
Total			4887	1046.5

For 15%CW replacement				
Sizes of aggregates		Thickness of gauge (0.6times the mean size of the two sieve sizes (mm)	Weight of the fraction (g)	Weight of the aggregate in each fraction passing(g)
Passing through (mm)	Retained on Sieve (mm)			
37.5	28	13.5	161.5	51.6
28	20	10.8	950.5	250.5
20	14	8.55	1716.5	421.5
14	10	6.75	850	281
10	6.3	4.89	255	71
Total			3933.5	1075.6

For 20%CW replacement				
Sizes of aggregates		Thickness of gauge (0.6times the mean size of the two sieve sizes (mm)	Weight of the fraction (g)	Weight of the aggregate in each fraction passing(g)
Passing through (mm)	Retained on Sieve (mm)			
37.5	28	13.5	165.5	47.5
28	20	10.8	901.5	201.5
20	14	8.55	1415.5	531

14	10	6.75	750	211
10	6.3	4.89	321	51
Total			3553.5	1042

B: TEST RESULTS

B: 1 Cube Compressive Strength Test Result of Concrete

Table 1B:1 Seventh day's compressive strength of concrete specimens prepared by partial replacement of sand with stone dust and coarse aggregate with ceramic waste

Specimen code	Specimen no	Dimension in cm			Mass in (gm)	Volume (cm3)	Failure load in KN	Compressive strength in Mpa
		L	W	H				
M00	1	15	15	15	8.489	3375	477	21.2
	2	15	15	15	8.324	3375	407	18.09
	3	15	15	15	8.626	3375	396	17.6
	mean						426.67	18.97
M25	1	15	15	15	8.425	3375	384.01	17.06
	2	15	15	15	8.365	3375	371.47	16.51
	3	15	15	15	8.304	3375	394.77	17.55
	mean						383.41	17.06
M50	1	15	15	15	8.420	3375	434	19.28
	2	15	15	15	8.573	3375	420.06	18.67
	3	15	15	15	8.39	3375	405	18
	mean						419.68	18.65
M75	1	15	15	15	8.456	3375	362	16.09
	2	15	15	15	8.623	3375	402	17.86
	3	15	15	15	8.447	3375	378	16.80
	mean						380.67	16.92
M100	1	15	15	15	8.575	3375	405	18
	2	15	15	15	8.875	3375	325	14.44
	3	15	15	15	8.589	3375	355	15.78
	mean						361.67	16.07

Table 1B:2 Fourteen day's compressive strength of concrete specimens prepared by partial replacement of sand with stone dust and coarse aggregate with ceramic waste

Specimen code	Specimen no	Dimension in cm			Mass in (gm)	Volume (cm3)	Failure load in KN	Compressive strength in Mpa
		L	W	H				
M00	1	15	15	15	8.425	3375	546.7	24.29
	2	15	15	15	8.365	3375	568.68	25.27
	3	15	15	15	8.304	3375	554.2	24.63
	mean						556.53	24.73
M25	1	15	15	15	8.420	3375	511.22	22.72
	2	15	15	15	8.573	3375	457.14	20.31
	3	15	15	15	8.39	3375	578.83	25.72
	mean						515.73	22.92
M50	1	15	15	15	8.489	3375	532.35	23.66
	2	15	15	15	8.324	3375	510.38	22.68
	3	15	15	15	8.626	3375	561.08	24.93
	mean						534.6	23.76
M75	1	15	15	15	8.456	3375	475.74	21.14
	2	15	15	15	8.623	3375	454.61	20.20
	3	15	15	15	8.447	3375	504.46	22.42
	mean						478.27	21.25
M100	1	15	15	15	8.575	3375	457.14	20.31
	2	15	15	15	8.875	3375	455.45	20.24
	3	15	15	15	8.589	3375	445.31	19.79
	mean						452.63	20.11

Table2B:3 Twenty-eight day's compressive strength of concrete specimens prepared by partial replacement of sand with stone dust and coarse aggregate with ceramic waste.

Specimen code	Specimen no	Dimension in cm			Mass in (gm)	Volume (cm3)	Failure load in KN	Compressive strength in Mpa
		L	W	H				
M00	1	15	15	15	8.225	3375	649	28.84
	2	15	15	15	8.171	3375	675	30
	3	15	15	15	8.364	3375	667.16	29.66
	mean						663.7	29.5
M25	1	15	15	15	8.5	3375	607	28.44
	2	15	15	15	8.49	3375	542	27.33
	3	15	15	15	8.12	3375	690	30.22
	mean						613	27.24
M50	1	15	15	15	8.44	3375	640	
	2	15	15	15	8.64	3375	615	
	3	15	15	15	8.44	3375	680	
	mean						645	28.66
M75	1	15	15	15	8.44	3375	586	26.04
	2	15	15	15	8.69	3375	539	23.95
	3	15	15	15	8.52	3375	654	29.067
	mean						593	26.35
M100	1	15	15	15	8.49	3375	560	24.88
	2	15	15	15	8.59	3375	546	24.26
	3	15	15	15	8.77	3375	573	25.46
	mean						559	24.87

B: 2 Flexural Strength Test Result of Concrete

Table 2B:1 7th ,14th and 28th day's flexural beam of concrete specimens prepared by partial replacement of sand with SD and coarse aggregate with ceramic waste

7th day flexural test result							
Designation	Percentage of CW $ SD	Beam Load (KN)			Avg. Load (KN)	Strength in (Mpa)	Variation from control
		1	2	3			
M00	0%CW+0%SD	18.6	17.94	17.92	18.05	5.41	-
M25	5%CW+25%SD	18.37	13.89	17.16	16.14	4.84	-11.77
M50	10%CW+50%SD	18.55	17.85	14.83	17.07	5.12	-5.66
M75	15%CW+75%SD	16.32	14.81	15.19	15.44	4.63	-16.84
M100	20%CW+100%SD	15.32	14.71	14.19	14.74	4.42	-22.39
14th day flexural test result							
Designation	Percentage of CW $ SD	Beam Load (KN)			Avg. Load (KN)	Strength in (Mpa)	Variation from control
		1	2	3			
M00	0%CW+0%SD	22.46	21.56	20.457	25.43	6.44	-
M25	5%CW+25%SD	20.36	19.65	19.61	23.52	5.95	-8.22
M50	10%CW+50%SD	21.23	21.49	19.51	24.55	6.21	-3.67
M75	15%CW+75%SD	19.40	19.8	18.59	22.83	5.78	-11.38
M100	20%CW+100%SD	19.29	17.3	16.74	21.05	5.33	-20.92
28th day flexural test result							
Designation	Percentage of CW $ SD	Beam Load (KN)			Avg. Load (KN)	Strength in (Mpa)	Variation from control
		1	2	3			
M00	0%CW+0%SD	26.58	25.52	24.21	25.43	7.63	-
M25	5%CW+25%SD	24.1	23.26	23.21	23.52	7.05	-8.22
M50	10%CW+50%SD	25.13	25.44	23.1	24.55	7.36	-3.67
M75	15%CW+75%SD	22.97	23.5	22	22.83	6.85	-11.38
M100	20%CW+100%SD	22.83	20.5	19.81	21.05	6.31	-20.92

B: 3 Split tensile Strength Test Result of Concrete

Table 3B1: Seventh day's Split tensile of concrete specimens prepared by partial replacement of sand with stone dust and coarse aggregate with ceramic waste

Specimen code	Specimen no	Dimension in (cm)		Volume in(cm3)	Peak load (KN)	Split tensile strength in (Mpa)
		L	D			
M00	1	20	10	1570.8	84	2.36
	2	20	10	1570.8	80	2.29
	3	20	10	1570.8	75	3.32
				mean	79	2.535
M25	1	20	10	1570.8	74	2.37
	2	20	10	1570.8	72	1.82
	3	20	10	1570.8	73	2.71
				mean	73	2.32
M50	1	20	10	1570.8	85	2.547
	2	20	10	1570.8	75	2.67
	3	20	10	1570.8	74	2.388
				mean	78	2.484
M75	1	20	10	1570.8	74.23	2.42
	2	20	10	1570.8	57.1	2.26
	3	20	10	1570.8	6885	2.16
				mean	72.11	2.29
M100	1	20	10	1570.8	60.5	1.93
	2	20	10	1570.8	78	2.5
	3	20	10	1570.8	58	1.84
				mean	85.5	2.09

Table 3B:2: 14th day'sSplit tensile of concrete specimens prepared by partial replacement of sand with stone dust and coarse aggregate with ceramic waste

Specimen code	Specimen no	Dimension in (cm)		Volume in(cm3)	Peak load (KN)	Split tensile strength in (Mpa)
		L	D			
M00	1	20	10	1570.8	85.34	2.73
	2	20	10	1570.8	105.6	3.2
	3	20	10	1570.8	113.23	3.62
				mean	101.4	3.21
M25	1	20	10	1570.8	109.85	3.44
	2	20	10	1570.8	87.03	3.28
	3	20	10	1570.8	85.34	2.23
				mean	94.04	2.99
M50	1	20	10	1570.8	108.16	3.49
	2	20	10	1570.8	104.78	2.77
	3	20	10	1570.8	83.65	2.74

				mean	98.86	3.14
M75	1	20	10	1570.8	95.48	2.4
	2	20	10	1570.8	81.96	3.1
	3	20	10	1570.8	81.12	2.5
				mean	86.19	2.74
M100	1	20	10	1570.8	92.95	2.96
	2	20	10	1570.8	75.20	2.26
	3	20	10	1570.8	85.34	2.58
				mean	84.5	2.65

Table 3B:3: Twenty-eight day's Split tensile of concrete specimens prepared by partial replacement of sand with SD and coarse aggregate with CW

Specimen code	Specimen no	Dimension in (cm)		Volume in(cm3)	Peak load (KN)	Split tensile strength in (Mpa)
		L	D			
M00	1	20	10	1570.8	101	3.2
	2	20	10	1570.8	125	3.98
	3	20	10	1570.8	134	4.26
				mean	120	3.81
M25	1	20	10	1570.8	130	4.14
	2	20	10	1570.8	103	3.28
	3	20	10	1570.8	101	3.216
				mean	111.33	3.54
M50	1	20	10	1570.8	128	4.07
	2	20	10	1570.8	124	3.95
	3	20	10	1570.8	99	3.15
				mean	117	3.72
M75	1	20	10	1570.8	113	3.59
	2	20	10	1570.8	97	3.1
	3	20	10	1570.8	96	3.05
				mean	102	3.25
M100	1	20	10	1570.8	110	3.5
	2	20	10	1570.8	89	2.83
	3	20	10	1570.8	101	3.216
				mean	100	3.18

C: STRAIN -STRESS DIAGRAM OF CUBE TEST

TableC:1 Strain stress diagram for cube at 28day

Cube Control (0%)								
Load in (KN)			area (mm2)	strain	Stress (Mpa)			
1	2	3			1	2	3	aver.
0	0	0	22500	0	0.000	0.0000	0.0000	0
18	21	18	22500	0.0000272	0.800	0.9333	0.8000	0.874
34	42	25	22500	0.000044	1.511	1.8667	1.1111	1.407
55	58	45	22500	0.000066	2.444	2.5778	2.0000	2.089
67	70	68	22500	0.0000933	2.978	3.1111	3.0222	2.919
88	89	96	22500	0.0001248	3.911	3.9556	4.2667	3.852
102	111	116	22500	0.0001567	4.533	4.9333	5.1556	4.77
137	139	138	22500	0.00019	6.089	6.1778	6.1333	5.719
179	188	174	22500	0.0002548	7.956	8.3556	7.7333	7.437
199	216	196	22500	0.000315	8.844	9.6000	8.7111	8.104
216	245	215	22500	0.00036	9.600	10.8889	9.5556	9.708
241	267	244	22500	0.00042	10.711	11.8667	10.8444	11.708
271	298	268	22500	0.00045	12.044	13.2444	11.9111	12.4
295	329	285	22500	0.000497	13.111	14.6222	12.6667	13.467
315	348	313	22500	0.000543	14.000	15.4667	13.9111	14.459
336	369	326	22500	0.000582	14.933	16.4000	14.4889	15.274
368	381	341	22500	0.000623	16.356	16.9333	15.1556	16.148
382	408	366	22500	0.000676	16.978	18.1333	16.2667	17.126
402	421	386	22500	0.000719	17.867	18.7111	17.1556	17.911
431	452	407	22500	0.000787	19.156	20.0889	18.0889	19.111
449	472	420	22500	0.000833	19.956	20.9778	18.6667	19.867
469	499	447	22500	0.000903	20.844	22.1778	19.8667	20.963
478	526	460	22500	0.000953	21.244	23.3778	20.4444	21.689
496	550	486	22500	0.001026	22.044	24.4444	21.6000	22.696
511	575	513	22500	0.001105	22.711	25.5556	22.8000	23.689

532	598	537	22500	0.001194	23.644	26.5778	23.8667	24.696
557	611	550	22500	0.001268	24.756	27.1556	24.4444	25.452
592	649	599	22500	0.001487	26.311	28.8444	26.6222	27.259
612	658	621	22500	0.001612	27.200	29.2444	27.6000	28.015
632	667	639	22500	0.00177	28.089	29.6444	28.4000	28.711
649	675	650	22500	0.002024	28.844	30.0000	28.8889	29.244
647	673	656	22500	0.0021	28.756	29.9111	29.1556	29.5
643	662	660	22500	0.00228	28.578	29.4222	29.3333	29.111
637	651	664	22500	0.002372	28.311	28.9333	29.5111	28.919
617	622	663	22500	0.002583	27.422	27.6444	29.4667	28.178
611	605	660	22500	0.002664	27.156	26.8889	29.3333	27.793
607	600	657	22500	0.002698	26.978	26.6667	29.2000	27.615
599	593	646	22500	0.002795	26.622	26.3556	28.7111	27.23
592	587	639	22500	0.002841	26.311	26.0889	28.4000	26.933
586	581	630	22500	0.002886	26.044	25.8222	28.0000	26.622
579	576	621	22500	0.00293	25.733	25.6000	27.6000	26.311
572	571	608	22500	0.002979	25.422	25.3778	27.0222	25.941
569	568	604	22500	0.002998	25.289	25.2444	26.8444	25.793

Cube (5%CW+25%SD)								
Load in (KN)			area (mm2)	strain	Stress (Mpa)			
1	2	3			1	2	3	aver.
0	0	0	22500	0	0	0	0	0
23	22	14	22500	0.0000272	1.022222	0.977778	0.622222	0.874
31	44	20	22500	0.000044	1.377778	1.955556	0.888889	1.407
48	64	29	22500	0.000066	2.133333	2.844444	1.288889	2.089
65	85	47	22500	0.0000933	2.888889	3.777778	2.088889	2.919
86	105	69	22500	0.0001248	3.822222	4.666667	3.066667	3.852
107	126	89	22500	0.0001567	4.755556	5.6	3.955556	4.77
121	147	118	22500	0.00019	5.377778	6.533333	5.244444	5.719

208	210	185	22500	0.0003139	9.244444	9.333333	8.222222	8.933
223	223	197	22500	0.0003383	9.911111	9.911111	8.755556	9.526
240	235	207	22500	0.0003625	10.66667	10.44444	9.2	10.104
258	259	227	22500	0.0004	11.46667	11.51111	10.08889	11.022
296	290	265	22500	0.0004745	13.15556	12.88889	11.77778	12.607
312	316	290	22500	0.0005224	13.86667	14.04444	12.88889	13.6
338	342	312	22500	0.0005781	15.02222	15.2	13.86667	14.696
356	356	342	22500	0.0006272	15.82222	15.82222	15.2	15.615
379	378	371	22500	0.0006892	16.84444	16.8	16.48889	16.711
393	392	401	22500	0.0007407	17.46667	17.42222	17.82222	17.57
431	423	458	22500	0.0008636	19.15556	18.8	20.35556	19.437
443	434	495	22500	0.0009285	19.68889	19.28889	22	20.326
467	458	524	22500	0.0010198	20.75556	20.35556	23.28889	21.467
490	482	567	22500	0.0011415	21.77778	21.42222	25.2	22.8
522	497	611	22500	0.0012888	23.2	22.08889	27.15556	24.148
532	510	630	22500	0.0013695	23.64444	22.66667	28	24.77
541	516	648	22500	0.0014414	24.04444	22.93333	28.8	25.259
558	522	657	22500	0.0015213	24.8	23.2	29.2	25.733
567	528	673	22500	0.001613	25.2	23.46667	29.91111	26.193
578	534	682	22500	0.0017094	25.68889	23.73333	30.31111	26.578
597	540	690	22500	0.0018955	26.53333	24	30.66667	27.067
605	541	685	22500	0.0021	26.88889	24.04444	30.44444	27.244
607	542	680	22500	0.0022931	26.97778	24.08889	30.22222	27.096
603	536	676	22500	0.0024016	26.8	23.82222	30.04444	26.889
601	530	670	22500	0.0024822	26.71111	23.55556	29.77778	26.681
596	526	655	22500	0.0025921	26.48889	23.37778	29.11111	26.326
587	519	640	22500	0.0027078	26.08889	23.06667	28.44444	25.867
574	508	625	22500	0.0028308	25.51111	22.57778	27.77778	25.289
554	501	616	22500	0.0029303	24.62222	22.26667	27.37778	24.756

544	496	609	22500	0.0029865	24.17778	22.04444	27.06667	24.43
539	490	604	22500	0.0030256	23.95556	21.77778	26.84444	24.193
534	488	598	22500	0.0030565	23.73333	21.68889	26.57778	24
524	478	592	22500	0.0031158	23.28889	21.24444	26.31111	23.615

Cube (10%CW+50%SD)								
Load in (KN)			area (mm2)	strain	Stress (Mpa)			
1	2	3			1	2	3	aver.
0	0	0	22500	0	0	0	0	0.000
18	21	19	22500	2.67E-05	0.8	0.933333	0.844444	0.859
34	37	24	22500	0.000044	1.511111	1.644444	1.066667	1.407
56	62	40	22500	0.000074	2.488889	2.755556	1.777778	2.341
76	87	58	22500	0.000105	3.377778	3.866667	2.577778	3.274
96	108	78	22500	0.000135	4.266667	4.8	3.466667	4.178
172	198	124	22500	0.000247	7.644444	8.8	5.511111	7.319
198	220	140	22500	0.000283	8.8	9.777778	6.222222	8.267
211	242	168	22500	0.00032	9.377778	10.75556	7.466667	9.200
231	258	196	22500	0.000358	10.26667	11.46667	8.711111	10.148
246	278	216	22500	0.000392	10.93333	12.35556	9.6	10.963
268	302	232	22500	0.000431	11.91111	13.42222	10.31111	11.881
292	322	258	22500	0.000477	12.97778	14.31111	11.46667	12.919
333	345	278	22500	0.000535	14.8	15.33333	12.35556	14.163
361	363	296	22500	0.000581	16.04444	16.13333	13.15556	15.111
411	404	333	22500	0.00068	18.26667	17.95556	14.8	17.007
425	425	356	22500	0.000728	18.88889	18.88889	15.82222	17.867
440	438	374	22500	0.000768	19.55556	19.46667	16.62222	18.548
466	471	420	22500	0.000865	20.71111	20.93333	18.66667	20.104
488	489	441	22500	0.000926	21.68889	21.73333	19.6	21.007
499	508	459	22500	0.000978	22.17778	22.57778	20.4	21.719
509	528	475	22500	0.00103	22.62222	23.46667	21.11111	22.400

528	544	492	22500	0.001093	23.46667	24.17778	21.86667	23.170
546	568	518	22500	0.001184	24.26667	25.24444	23.02222	24.178
566	582	543	22500	0.001273	25.15556	25.86667	24.13333	25.052
589	596	568	22500	0.00138	26.17778	26.48889	25.24444	25.970
606	605	591	22500	0.00148	26.93333	26.88889	26.26667	26.696
624	611	614	22500	0.001598	27.73333	27.15556	27.28889	27.393
635	615	625	22500	0.001679	28.22222	27.33333	27.77778	27.778
640	611	636	22500	0.001722	28.44444	27.15556	28.26667	27.956
635	607	654	22500	0.001759	28.22222	26.97778	29.06667	28.089
630	604	664	22500	0.0021	28	26.84444	29.51111	28.119
615	598	671	22500	0.00251	27.33333	26.57778	29.82222	27.911
605	594	675	22500	0.00255	26.88889	26.4	30	27.763
598	586	679	22500	0.002591	26.57778	26.04444	30.17778	27.600
590	578	680	22500	0.002641	26.22222	25.68889	30.22222	27.378
585	568	675	22500	0.002705	26	25.24444	30	27.081
579	558	671	22500	0.002761	25.73333	24.8	29.82222	26.785
574	554	664	22500	0.002803	25.51111	24.62222	29.51111	26.548
569	548	658	22500	0.002845	25.28889	24.35556	29.24444	26.296
562	541	650	22500	0.002897	24.97778	24.04444	28.88889	25.970
555	534	638	22500	0.002955	24.66667	23.73333	28.35556	25.585
547	527	629	22500	0.003006	24.31111	23.42222	27.95556	25.230
541	521	616	22500	0.003056	24.04444	23.15556	27.37778	24.859

Cube (15%CW+75%SD)								
Load in (KN)			area (mm2)	strain	Stress (Mpa)			
1	2	3			1	2	3	aver.
0	0	0	22500	0	0	0	0	0
18	12	21	22500	2.35E-05	0.8	0.533333	0.933333	0.756
56	42	65	22500	7.69E-05	2.488889	1.866667	2.888889	2.415
73	64	91	22500	0.000109	3.244444	2.844444	4.044444	3.378

102	83	111	22500	0.000144	4.533333	3.688889	4.933333	4.385
168	126	183	22500	0.000243	7.466667	5.6	8.133333	7.067
182	142	206	22500	0.000274	8.088889	6.311111	9.155556	7.852
206	152	231	22500	0.000309	9.155556	6.755556	10.26667	8.726
223	163	259	22500	0.000344	9.911111	7.244444	11.51111	9.556
264	184	325	22500	0.000428	11.73333	8.177778	14.44444	11.452
328	228	419	22500	0.000578	14.57778	10.13333	18.62222	14.444
348	253	448	22500	0.000639	15.46667	11.24444	19.91111	15.541
360	268	471	22500	0.000682	16	11.91111	20.93333	16.281
382	283	505	22500	0.000748	16.97778	12.57778	22.44444	17.333
414	327	573	22500	0.000898	18.4	14.53333	25.46667	19.467
438	341	605	22500	0.000982	19.46667	15.15556	26.88889	20.504
452	368	620	22500	0.001056	20.08889	16.35556	27.55556	21.333
463	396	639	22500	0.001141	20.57778	17.6	28.4	22.193
484	422	645	22500	0.001228	21.51111	18.75556	28.66667	22.978
496	444	654	22500	0.001308	22.04444	19.73333	29.06667	23.615
512	456	650	22500	0.001358	22.75556	20.26667	28.88889	23.97
520	477	643	22500	0.001407	23.11111	21.2	28.57778	24.296
529	496	635	22500	0.001456	23.51111	22.04444	28.22222	24.593
536	507	621	22500	0.001466	23.82222	22.53333	27.6	24.652
545	521	615	22500	0.001512	24.22222	23.15556	27.33333	24.904
550	528	608	22500	0.001527	24.44444	23.46667	27.02222	24.978
557	536	601	22500	0.001551	24.75556	23.82222	26.71111	25.096
563	538	597	22500	0.001563	25.02222	23.91111	26.53333	25.156
570	539	592	22500	0.0021	25.33333	23.95556	26.31111	26.35
577	537	579	22500	0.002713	25.64444	23.86667	25.73333	25.081
581	526	560	22500	0.002805	25.82222	23.37778	24.88889	24.696
586	514	558	22500	0.002834	26.04444	22.84444	24.8	24.563
584	509	553	22500	0.002872	25.95556	22.62222	24.57778	24.385

581	504	548	22500	0.002911	25.82222	22.4	24.35556	24.193
578	498	542	22500	0.002955	25.68889	22.13333	24.08889	23.97
570	491	537	22500	0.003011	25.33333	21.82222	23.86667	23.674
552	487	531	22500	0.003084	24.53333	21.64444	23.6	23.259
538	483	528	22500	0.003137	23.91111	21.46667	23.46667	22.948

D: FEA INPUT DATA

1. CONCRETE

Table D.1: Summary of concrete damage parameters

Concrete		Concrete Damage Parameter	
Grade	C25	Eccentricity	0.1
Density	2 .30E-09	Dilation angle(β)	35
Modulus of elasticity	28536.6	k	0.667
Poisson's ratio	0.18	σ_{b0}/σ_{c0}	1.16
		Viscosity parameter	0.0001

Table D.2: Compressive behavior of concrete damage plasticity for M00 specimen

compressive behavior		Compressive damage	
σ_c	e_{in}	e_{in}	d_c
0	0	0	0
11.708	0.00042	6.39E-06	0
12.4	0.00045	1.51E-05	0
13.467	0.000497	2.34E-05	0
14.459	0.000543	4.10E-05	0
15.274	0.000582	5.42E-05	0
16.148	0.000623	7.82E-05	0
17.126	0.000676	9.60E-05	0
17.911	0.000719	0.000125	0
19.111	0.000787	0.000148	0
19.867	0.000833	0.000184	0
20.963	0.000903	0.000226	0
21.689	0.000953	0.000278	0
22.696	0.001026	0.000324	0

23.689	0.001105	0.000395	0
24.696	0.001194	0.000476	0
25.452	0.001268	0.000572	0
26.415	0.001375	0.000705	0
27.259	0.001487	0.000939	0
28.015	0.001612	0.001006	0
28.711	0.00177	0.0012	0.005432
29.244	0.002024	0.001299	0.011992
29.5	0.0021	0.001368	0.018073
29.111	0.00228	0.001404	0.021626
28.919	0.002372	0.001472	0.029211
28.741	0.002434	0.001538	0.037308
28.637	0.002466	0.001633	0.050461
28.415	0.002526	0.001674	0.056543
28.178	0.002583	0.001744	0.062624
27.793	0.002664	0.001785	0.069696
27.615	0.002698	0.001842	0.079843
27.437	0.002762	0.001898	0.090468
27.23	0.002795	0.001953	0.101093
26.933	0.002841	0.002016	0.113734
26.622	0.002886	0.002041	0.118791
26.311	0.00293		
25.941	0.002979		

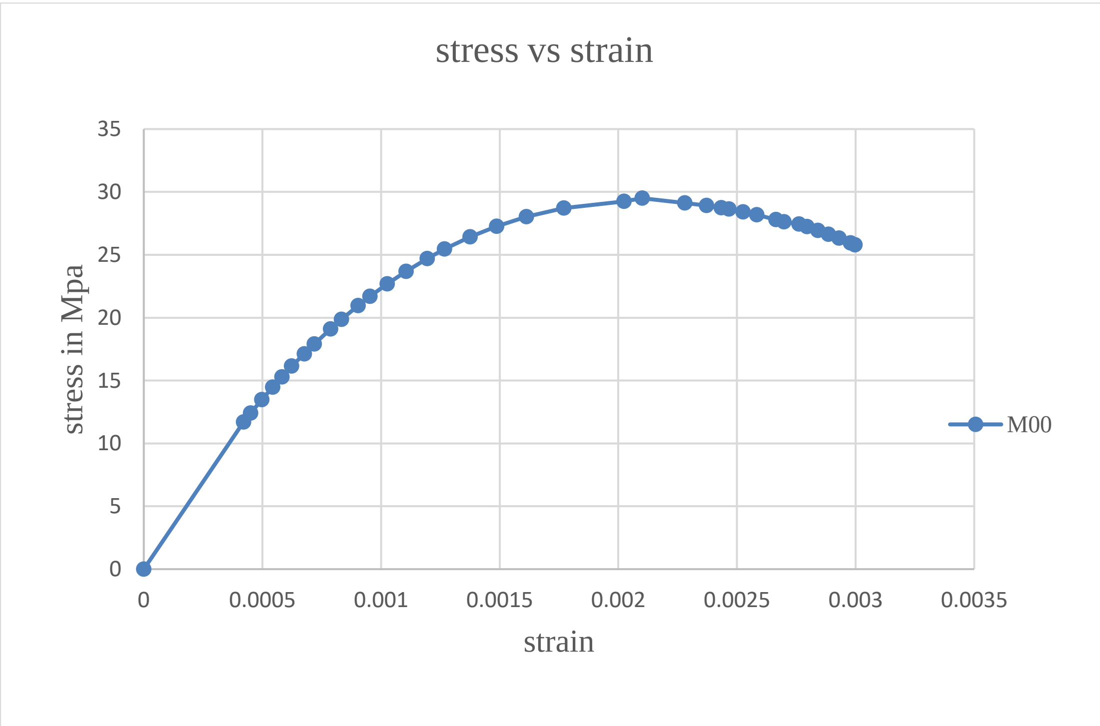


Figure D:1 Compressive stress versus inelastic strain

Table D:.3 Tensile behavior of concrete damage plasticity for Specimens M00

Tensile stress		Tension damage	
σ_t	ε_{cr}	d_t	ε_{cr}
3	0	0	0
1.664354	0.000281	0.445215	0.000281
1.179148	0.000507	0.606951	0.000507
0.923358	0.000718	0.692214	0.000718
0.76383	0.000923	0.74539	0.000923
0.654173	0.001124	0.781942	0.001124
0.573836	0.001324	0.808721	0.001324
0.512265	0.001522	0.829245	0.001522
0.463463	0.00172	0.845512	0.00172
0.423761	0.001917	0.858746	0.001917

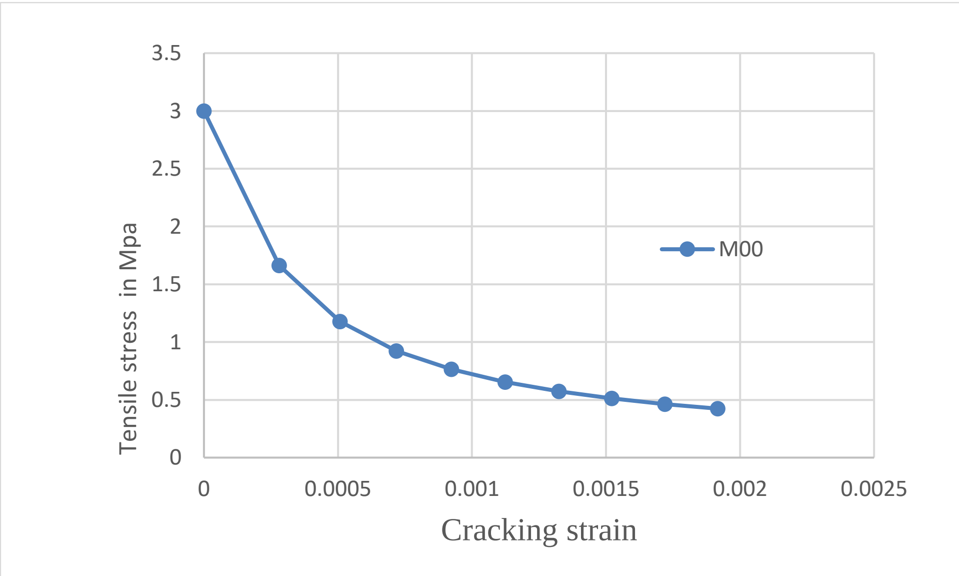


Figure D:2 Tensile stress versus cracking strain

E- SAMPLE PHOTO CAPTURED DURING LABORATORY EXPERIMENT