# EVALUATION OF PARTIAL REPLACEMENT OF CERAMIC TILES WITH COARSE AGGREGATE IN GRADE 20 CONCRETE.

**BY**

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## PLAGIARISM

This work **EVALUATION OF PARTIAL REPLACEMENT OF CERAMIC TILES WITH COARSE AGGREGATE IN GRADE 20 CONCRETE** by OLALEKAN, Taiwo Samuel with Number ENG2006203 of the Department of Civil Engineering, Faculty of Engineering, University of Benin City, Edo State, Nigeria, has passed the PLAGIARISM TEST.

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# DEDICATION

This project is dedicated to the Almighty God, my parents; Mr. and Mrs. Olalekan Bogunmbe, and brothers, for their support through my educational journey as a student of the University of Benin.

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## ABSTRACT

The need to reduce the increasing demand for crushed granite as coarse aggregate as well as the need to safeguard the environment from degradation has given rise to various researches on alternative materials that can serve the same purpose while minimizing environment hazard.

The suitability of waste ceramic tiles as coarse aggregate in concrete and ascertain its strength against normal crushed granite were assessed. Crushed waste ceramic tiles was mixed with crushed granite stones as partial replacement for concrete.

A mix ratio of 1: 2: 4, with attached mix design in appendix plate 1, for C20 concrete is produced with (0, 10, 20, 30, and 40) percent volume ceramic waste aggregate replacement for crushed granite at a constant water-cement ratio of 0.5. Concrete cubes of size 150mm x 150mm x 150mm were produced and tested for 7, 14 and 28 days for compressive strength, density and water absorption.

The results obtained shows that the compressive strength of concrete reduced gradually for all ages with the increase in percentage replacement. Ceramic wastes from the construction sites and manufacturing industries could be recycled by breaking them into various coarse aggregate sizes and used in concrete mixes. However, a maximum content of 20% ceramic waste aggregate replacement in a mix is ideal to produce the required strength and durability of structural concrete.

It was also observed that the percentage water absorption increased from 0% to 30%, it then dropped at 40% ceramic waste replacement of granite specimen. The increase in water absorption was probably due to relatively porous nature of the unpolished side of the ceramic waste as compared to the granite. It is therefore advised that coarse aggregate replacement must not exceed 20% since there was not much significant increase in water absorption up to this limit compared to the control. Meanwhile the density decreases with increase in percentage ceramic waste replacement, that is from 0% to 40%, for granite in the concrete produced.

With no doubt, this mode of recycling ceramic waste could positively sustain the environment.

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# CHAPTER ONE

# INTRODUCTION

## 1.1 BACKGROUND OF THE STUDY

The widespread use of concrete in modern construction highlights its importance as a fundamental building material. As the global demand for infrastructure, residential, and commercial buildings continues to escalate, the role of concrete in shaping the built environment becomes increasingly significant. However, the production of concrete is not without its environmental implications, particularly with regards to the extraction and processing of natural aggregates. Due to the modern civilization, the solid waste is increasing from the demolitions of constructions, because there is a huge usage of ceramic tiles in the construction field today. Ceramic products are part of the essential construction materials used in most buildings, like wall tiles, floor tiles, sanitary ware, household ceramics and technical ceramics and faucets. Solid waste generation is on the increase worldwide. Apart from defacing the landscape, they also constitute a major environmental hazard. In order to prevent the environment, there are several researches already concluded and there are also new ones being carried out to explore the reuse of solid waste, which the replacement of coarse aggregate with ceramic tiles is one to look out for.

Ceramic tiles waste**,** like many other solid wastes, have been found to improve concrete properties. Since they are non-biodegradable in nature and because of their high collection from destroyed buildings, the imperative to adopt sustainable practices in the construction industry has sparked a surge in research endeavors focused on identifying alternative materials and recycling strategies. One such initiative involves the reutilization of waste ceramics. It is produced in companies during or after production process due to errors in either construction, human activities, and inappropriate raw materials. It has been estimated that about 30% of daily production in the ceramic industry goes as waste.

Crushed waste ceramic tile powder and granite powder are used as a replacement to the coarse aggregates and fine aggregate. The ceramic waste crushed tiles were partially replaced in place of coarse aggregates by 0% to 40%. Granite powder and ceramic tile powder were replaced in place of fine aggregate by 10% along with the ceramic coarse tile. Grade 20 of concrete was designed and tested. The mix design for different types of mixes were prepared by replacing the coarse aggregates and fine aggregates at different percentages of crushed tiles and granite powder. Experimental investigations like workability, compressive strength test, split tensile strength test, and flexural strength test for different concrete mixes with different percentages of waste crushed and granite powder after 7, 14, and 28 days curing period was done.

(Mujedu, 2014) investigated the suitability of ceramic tiles as coarse aggregates in concrete production, and observed that the compressive strength and density are maximum for concrete cubes with 100% crushed tiles and minimum when broken tiles content is 100%. It was reported that replacement of crushed granite with 39% to 57% broken tiles content showed satisfactory result.

(Ikponmwosa and Ehikhuenmen, 2017) researched the effect of ceramic waste as coarse aggregate on strength properties of concrete. They applied replacement levels of 25%, 50%, and 75%. They concluded that ceramic waste tiles could be used for both structural and no structural works and recommended that beyond 75% replacement level, ceramic waste material should not be used in concrete structures. Where strength is the major consideration.

## 1.2 STATEMENT OF THE PROBLEM

The rapid growth of construction activities leads to increased generation of ceramic waste materials, which pose environmental and disposal concerns. Simultaneously, the depletion of natural aggregates raises brows about resources sustainability. Utilizing ceramic tile waste as a partial replacement for coarse aggregate in concrete not only offers an eco-friendly disposal method but potentially reduces construction costs.

However, replacing natural coarse aggregates with ceramic waste may influence concrete's compressive strength, workability, and overall performance. There is a lack of comprehensive understanding and standardized guideline regarding the optimal replacement levels that maintain structural integrity while prioritizing sustainability, which is the reason for this research.

In addition, by exploring the benefits and challenges of ceramic waste, this research can help mitigate the environmental footprint of concrete production while providing a solution for managing ceramic waste.

## 1.3 AIM AND OBJECTIVES

**AIM:** Evaluation of partial replacement of ceramic tiles with coarse aggregate in grade 20 concrete. The aim of this study will be achieved through the following objectives.

**OBJECTIVES**

a. Evaluation of concrete mixes with varying levels of ceramic tile replacement (0%, 10%, 20%, 30%, and 40%)

b. Evaluation of tests on fresh concrete (workability) and hardened concrete (compressive strength, flexural strength, split tensile strength.)

c. Evaluation of the influence of ceramic tile replacement on other properties such as water absorption and durability.
d. Evaluation of the density of the ceramic concrete.

## 1.4 SCOPE OF THE STUDY

The scope of this research is confined to the evaluation of coarse aggregate replacement with ceramic tiles in grade 20 concrete, which will involve the following areas:

i. Workability.
ii. Flexural strength.
iii. Compressive strength.
iv. Split tensile strength.
v. Water absorption.
vi. Density test.
vii. Impact value test.

## 1.5 JUSTIFICATION OF THE STUDY

The construction industry's substantial environmental awareness, characterized by extensive resource consumption and waste generation, highlights the need for sustainable practices. Recycling ceramic waste as a partial replacement for natural coarse aggregates in concrete offers a promising solution, addressing waste management concerns while conserving natural resources. The adoption of ceramic materials in concrete can also yield economic benefits, and foster the development of sustainable construction methodologies. However, the potential benefits of utilizing ceramic waste in concrete can only be fully realized if the material's performance is thoroughly understood. Without comprehensive research, concerns regarding reduced strength, durability, or other mechanical properties may hinder widespread adoption. This study seeks to bridge this knowledge gap by conducting a systematic investigation into the mechanical behavior of concrete while incorporating ceramic waste. The findings of this research can inform the development of standards and guidelines, ultimately promoting the use of environmentally friendly construction solutions that support sustainable development.

# CHAPTER TWO

# LITERATURE REVIEW

It has been established from the previous chapter that concrete is the world's most used material, and the production of concrete relies to a large extent on the availability of cement, sand and coarse aggregates such as granite, the costs of which have risen astronomically over the past few years. Being the major component of structure, many researches have been done on concrete to improve its properties in every possible manner to develop a sustainable concrete mass. The concrete can be strengthened only by the replacement of its ingredients by better ones. Not only replacing by some materials, but using a waste material makes the environment friendly and suitable to construction. In this aspect, lots of researches have been done on using the tile aggregate in concrete directly from industry or indirectly from demolition of a structure.

The present study is focused only on the literature related to usage of tile aggregate in concrete as a replacement to coarse aggregate. Some of previous studies have investigated the use of ceramic wastage in concrete as coarse aggregate, which will be reviewed below:

Odero, 2014, observed that partial replacement of concrete aggregate with ceramic tile does not alter the British Standard requirement (BS EN 12620:2013) for aggregates used in concrete. Construction industry has the capacity to be the end user of virtually all the ceramic materials thus solving the environmental problem moderately on its own. Adoption of waste products in concrete not only solves disposal issues but it is also economical. Crushed ceramic waste aggregate has the capacity to be used to produce light weight concrete without upsetting the strength.

In 2013, Sudarsana Rao Hunchate submitted on the influence of water absorption of ceramic waste aggregate on strength properties of ceramic aggregate concrete. Grade 20 concrete is used with 0.48 water cement ratio. Ceramic waste water absorption is 0.08% more than conventional aggregate. Compressive strength is best at 20% replacement reaching 93.45%, 98.84% to that of conventional concrete at 7 and 28 days. There is decrease in density with increase of percentage replacement; at 100% replacement density is 4.43% less when compared to conventional concrete.

(Amir Javed, 2015). On the compressive and flexural strength of concrete with stone dust as natural sand at 20%, 40%, 60%, 80% and 100% along with ceramic waste as stone aggregate at 20% replacement. It is found that at 40% stone dust and 20% ceramic waste compressive strength reaches up to 77.32% of that of conventional concrete whereas there is an increased in flexure strength by 25.62%.

(Tavakoli, 2013) investigated on the possibility of using ceramic tile in concrete. Coarse aggregate is replaced in the range of 0-40%. There is an increase in compressive strength by 5.13% whereas there is a decrease in slump, water absorption and unit weight by 10%, 0.1% and 2.29% respectively with 10% substitution.

There have been various researches conducted on the exploitation of solid waste products in concrete as they contribute in the environmental damage and chronic shortage of construction materials because of the high demand for raw materials by construction industry. A research by Sekar, in 2011 established through testing that compressive strength of concrete cubes made with glass insulator and ceramic insulator were determined to be 26.34% and 16% respectively less than the conventional concrete.

Giridhar, 2015, experimented on concrete with ceramic waste as natural coarse aggregate at 0%, 20%, 40%, 60%, 80% and 100%. Grade 20 concrete is adopted. Maximum compression attained at 20% replacement reached 93.45% and 98.84% to that of conventional concrete. Similarly split tensile strength reaches 97.38% and 93.78% to that of conventional concrete at 7 and 28 days respectively.

Tabak (2012), studied on the mechanical and physical properties of concrete produced form Floor Tiles Waste Aggregate (FTWA). Two samples were made - the first one substitution by Floor Tile Waste Dust (FTDA) and the other a combination of Floor Tile Waste Dust (FTDA) and Floor Tile Waste Aggregate (FTWA). Best result is shown by FTWA substitution. Increase in compression strength is 13.53%, 16.70% and 2.91% for 2, 7, and 28 days. Similarly, there is an increase of 23.21%, 0.1% and 19.47% respectively for flexure strength. There is a reduction of specific density and water absorption of 0.284Kg/m3 and 0.158% respectively when compared to conventional concrete.

**2.1 AGGREGATES**

Aggregates are materials like sand, gravel, or crushed stone that are mixed with cement and water to make concrete. They make up about 60–80% of the concrete volume, so their quality matters a lot. Aggregates are the backbone of concrete, and their type affects the strength, weight, durability, and cost of construction.

They can be classified based on how they are formed or how much they weigh. Depending on whether you need a strong bridge, a lightweight roof, or a radiation-proof wall, you'll choose different types of aggregates - natural or artificial, light or heavy.

## 2.2 CLASSIFICATION OF AGGREGATES

a. Natural aggregates.

b. Artificial aggregates.

c. Normal aggregates.

d. Light aggregates.

e. Heavy aggregates

### 2.2.1 NATURAL AGGREGATES

Natural aggregates are those that come from natural sources, such as riverbeds, mountains, or lakes. They are obtained without changing their natural form too much—just by crushing, washing, or sorting.

Examples:

1. Sand (from rivers or beaches)
2. Gravel (rounded stones from rivers)
3. Crushed stone (from rocks like limestone or granite)

Types of Rocks Used:

i. Igneous rocks: The most common are the granites and basalts. Granitic aggregates are commonly used because they are hard, tough and dense and are excellent in bonding with cement. Although it's excellent in concrete production, its overexploitation has adversely affected the environment thus the need for research on alternatives.

ii. Sedimentary rocks (e.g., limestone, sandstone): They are used as aggregates due to their varied composition and properties. They are widely available and can be extracted from quarries. Different types of sedimentary rocks can be used for various applications, depending on their properties. However, they have such limitations as durability and strength variability.

iii. Metamorphic rocks (e.g., marble, quartzite): They are usually massive, dense and adequately tough thus provide good aggregates. However, schists and slates are often thinly laminated and are therefore unsuitable. Other rocks such as shale and sandstones among others are rarely available. Shales are poor aggregates because they are weak, soft and absorptive. In sandstones, imperfect cementation of constituent grains makes some sandstone friable and very porous thus unsatisfactory aggregates. Since natural aggregates are formed by geological processes or by crushing rock, their many properties depend on the properties of the parent rock e.g. chemical and mineral composition, petrology, specific gravity, hardness, strength, pore structure, color etc. these properties have a considerable influence on the quality of fresh and hardened concrete.

Uses:

i. Making concrete and mortar
ii. Road construction
iii. Drainage systems

### 2.2.2 ARTIFICIAL AGGREGATES

Artificial aggregates are made by humans using industrial processes or by-products. They are not naturally occurring in their final form.

Examples:

i. Fly ash aggregates (made from coal power plant ash)
ii. Expanded clay or shale (heated in a kiln to form lightweight balls)
iii. Blast furnace slag (a by-product of steel manufacturing)

iv. Recycled concrete aggregates (old concrete crushed and reused)

Advantages:

i. Help reduce waste
ii. Can be made lightweight or strong depending on the process
iii. Eco-friendly (especially recycled ones)

Uses:

i. Lightweight concrete
ii. Insulating walls
iii. Non-structural elements

### 2.2.3 NORMAL WEIGHT AGGREGATES

These aggregates have a standard or average density, usually between 2,400–2,800 kg/m³, depending on their mix proportion. They are the most commonly used in construction as many of the natural aggregates like granites, gravels, basalts, limestone among others fall under this category. All these aggregates have specific gravities within a limited range of 2.55-2.75.

Examples:

i. Crushed stone
ii. Natural sand
iii. Gravel

Uses:

i. Everyday concrete work (beams, slabs, columns)
ii. Bridges, buildings, roads.

Density Range:

i. 2.4–2.8 g/cm³ (or 2,400–2,800 kg/m³)

### 2.2.4 LIGHTWEIGHT AGGREGATES

These aggregates are less dense and are used to make lightweight concrete. They are useful where less weight is needed without compromising strength, like the self-weight (dead loads) of a structure. They have better thermal insulation than normal weight aggregates. The reduced specific gravity is obtained from air voids within the aggregate particles. Their lightweight (low concrete strength) is as a result of their low specific gravity and increase in porosity.

Most artificial aggregates fall under this category, like, sintered PFA, LECA, Foamed slag etc., except for some natural lightweight aggregates like Pumice. It is a naturally occurring volcanic rock of low density. It has been used since Roman times but it is only available in few locations e.g. in Kenya, it is found in Longonot, Rift valley province.

Examples:

i. Pumice (a volcanic rock full of air pockets)
ii. Expanded clay, shale, or slate.
iii. Perlite (volcanic glass expanded by heat)
iv. Foamed slag.

Advantages:

i. Reduces overall weight of the structure.
ii. Better insulation against heat and sound.
iii. Easier to handle and transport

Uses:

i. Roof slabs and walls.
ii. Prefabricated blocks.
iii. Floating structures.

Density Range:

i. 300–1,850 kg/m³ (KM Brooks, 1991)

### 2.2.5 HEAVYWEIGHT AGGREGATES

These are very dense aggregates, used where high weight or radiation shielding is needed.

Examples:

i. Barite (a heavy mineral)
ii. Magnetite
iii. Hematite
iv. Steel or iron shot
v. Scrap metal

Advantages:

i. Provides protection from radiation
ii. Helps in stability (e.g., counterweights)

Uses:

a. Nuclear power plant walls
b. Medical radiation rooms (X-ray, CT scan)
c. Ballast for bridges or offshore structures

Density Range:

i. 3,200–6,400 kg/m³ or more

**2.3 CERAMIC WASTES**

Ceramic wastes come from two sources. The first source is the ceramics industry, which is classified as non-hazardous industrial waste, according to the Integrated National Plan on Waste (NHIW) 2008-2015, Order MAM/304/2002, in accordance with the European List of Waste (ELW) and identified according to the following: wastes generated by structural ceramic plants that only use red pastes to produce their products such as blocks, brick, and roof tiles.

The second source of ceramic waste is associated with construction and demolition activity, and constitutes a significant fraction of construction and demolition waste (CDW). This category uses white and red pastes. However, the use of white paste is more common and is produced in higher volume.

Nigeria is a developing country, with a land area of 923,768 km$^2$, and a population of about 140 million with growth rate of 2.38%. Nigeria is the most populous country in Africa and ninth most populous country in the world. With populations distributed at 48.3% urban and 57.7% rural and population density at 139 people per square km (Ogwueleka, 2009). The volume of solid waste being generated continues to increase at a faster rate than the ability of the agencies to improve on the financial and technical resources needed to parallel this growth. Having carried out a municipal solid waste characteristics and management in Nigeria, eight cities in the Federal Republic of Nigeria which are Maiduguri, Kano, Abuja, Onitsha, Nsukka, Makurdi, Ibadan and Lagos show that 35.6%, 32%, 38.6%, 33.8%, 20.2%, 25.8%, 13.5%, 36% of solid waste were glass and ceramics, respectively.

Globally, the ceramic industry sector is unusual in that it is primarily found in regional concentrations where the majority of agents or industries involved in the system whereby the end ceramic product attains value are located. The development of these ceramic “clusters” with 7

companies in the same or related sectors located in geographical proximity, has enabled the sector globally to attain a state-of-the-art level of progress and technological innovation. The main ceramic “clusters” are located in Brazil, with one in Santa Catarina and two in the state of Sao Paulo; in Portugal, in the Aveiro region; in Castellón, Spain; and in the province of Emilia Romagna, Italy. The ceramics industry in China has also begun to take on greater prominence, representing 35% of global production in recent years. The ceramics industry is of the following subsectors: wall and floor tiles, sanitary ware, bricks and roof tiles, refractory materials, technical ceramics and ceramic materials for domestic and ornamental use. In both the European Union and Spain, the scale of production within these subsectors with regard to total production follows the same trends, where the production of wall and floor tiles represents the highest percentage with respect to the total, followed by bricks and roof tiles, and finally, the other subsectors.

Ceramic products are produced from natural materials containing a high proportion of clay minerals. Following a process of dehydration and controlled firing at temperatures between 700ºC and 1000ºC. These minerals acquire the characteristic properties of fired clay. Ceramic factory waste is not sorted according to the reason for rejection, which may include: breakage or deformation and firing defects (Frías, 2008).

As regards waste generated by construction activity, it is estimated that some 200 million tons of rubble is produced each year in the European Union (EU) as a result of the construction and demolition of buildings. According to data from the Spanish National Plan for Construction and

Demolition Waste, 40 million tons are generated annually in Spain. The equivalent of 2kg per inhabitant per day, which represents a higher figure than that for domestic waste. Within the EU as a whole, 28% of this waste is recycled. Pioneering European countries in this matter include the Netherlands, where 95% of construction waste is recycled. England, with 45% and Belgium with 87%, 17% of which is used in making concrete. In Spain, approximately 10% of total 8

construction and demolition waste is recycled, and reuse mainly consists of using the waste for road subgrade and subbase (Binici, 2007).

### 2.3.1 CERAMIC WASTE RECYCLING

Ceramic waste has been tested as a partial replacement of traditional coarse aggregate, effects are promising but they underachieve in water absorption hence ceramic waste use as a fine aggregate is a better choice (Pacheco-Torgal, 2010).

Ceramic tiles were obtained from manufacturing industries and construction and demolition sites, which causes environmental pollution. The utilization of crushed tile as a coarse aggregate in concrete would also have a positive effect on the economy. Ceramic tile wastes were used in concrete as a replacement for natural coarse aggregate with 0%, 10%, 20% and 30% of the substitution and M20 grade concrete was used. The concrete moulds were casted and tested for Compressive Strength and Split Tensile Strength after a curing period of 3, 7 & 28 days. The results indicate that, the maximum compressive strength is obtained for the 30% replacement of ceramic tile aggregate with natural coarse aggregate (Prof. Shruthi, 2016).

Weil, Jeske & Schebek, in 2016 submitted that Europe has begun using recycled aggregate for the production of new concrete. Civil engineers in Europe had adopted recycled aggregate; bricks, recycled concrete and ceramics as fill material.

Crushed ceramic waste aggregate has the property to produce lightweight concrete without interfering with strength.

### 2.3.2 MERITS OF RECYCLING CERAMIC WASTE (CCW)

Recycling crushed ceramic waste offers a range of benefits that can contribute to a more sustainable and environmentally friendly construction industry. Advantages of using ceramic waste in concrete:

a. Environmental Benefits

This use leads to removal of those ceramic waste materials from disposal sites (Nadeem, 2012). Environmental benefit as a result of reduction in the utilization of natural resources such as raw construction material (Sekar, 2011). Sand mining in rivers lowers the water table.

i. Conservation of natural resources: Recycling ceramic waste reduces the need for extracting and processing raw materials from natural sources.
ii. Waste reduction: recycling ceramic waste helps divert waste from landfills with waste disposal.
iii. Energy savings: Recycling ceramic waste can reduce the energy required to produce new ceramic products.

b. Economic Benefits

i. Cost savings: Recycling ceramic waste can be more cost-effective than producing new materials from new materials from raw sources.

ii. New revenue streams: Recycling ceramic waste can create new business opportunities and revenue streams.

iii. Job creation: The recycling industry can create employment opportunities in collection, processing, and manufacturing.

c. Construction Benefits

Lower self-weight of concrete produced due to ceramic's low density than conventional crushed stone aggregate (Tavakoli, Heidari and Karimian, 2013).

i. Improved sustainability: Using recycled ceramic waste in construction projects can contribute to sustainable building practices.

ii. Enhanced durability: Recycled ceramic waste can be used to produce aggregate and other materials that improve the durability of construction projects.

iii. Reduced environmental impact: Recycling ceramic waste in construction can reduce the environmental footprint of building projects.

### 2.3.3 CHEMICAL PROPERTIES OF CERAMIC WASTE

**i.** CHEMICAL COMPOSITION

Ceramic waste chemical properties can vary depending on the type of ceramic material and its composition. Its composition of raw material is not significantly different from that of ceramic products. However, some common significant chemical properties of ceramic tiles are Silicon dioxide ($SiO_2$), Aluminum oxide ($Al_2O_3$), and Metal oxides, and they depend on the clay used. The red paste in ceramics contains a high percentage of iron oxide and is responsible for the red color.

ii. CHEMICAL REACTIVITY

Many ceramic materials are chemically inert, meaning they do not react with other substances easily. They are often resistance to corrosion and chemical attack.

iii. POTEENTIAL ENIRONMENT IMPACTS

Depending on the composition of the ceramic waste, there is a potential for leaching of chemicals into the environment. The chemical stability of ceramic waste can also affect its suitability for various applications, including construction and environmental uses.

### 2.3.4 PHYSICAL PROPERTIES OF CERAMIC WASTE

Based on experimental research, water absorption of ceramic waste was 0.18% and that for natural aggregate was 0.10%. Ceramic waste has higher water absorption because of pore structure, surface area and clay content. Ceramic aggregate has a crystalline structure (Sudarsana Rao Hunchate, 2013). Specific gravity of fine aggregate from ceramic waste depends on the chemical composition of the ceramics. Siddesha used homogenous ceramic tiles with physical properties (Siddesha, 2011).

The physical properties of ceramic waste can vary depending on the type of ceramic material and its composition. Some common properties include:

i. PHYSICAL CHARACTERISTICS

a. Hardness: Ceramic materials are often hard and resistant to abrasion.
b. Density: The density of ceramic waste can vary, but it is often relatively high.
c. Porosity: Some ceramic materials are porous, while others are non-porous.

ii. PERTICLE SIZE AND SHAPE

a. Particle size distribution: The size and distribution of particles in ceramic waste can affect its physical properties and potential uses.
b. Particle shape: The shape and ceramic particles can influence their behavior in various applications.

## 2.4 PROPERTIES OF CRUSHED CERAMIC WASTE CONCRETE

Punit Malik from Department of Civil Engineering, Dronacharya College of Engineering, in India designed class 25 concrete (25MPa) using natural fine aggregate and crushed ceramic tiles coarse aggregate. Punit Malik concluded that:

i. The mass of aggregate reduced by 50% which consequently reduced the weight of concrete.
ii. Ceramic waste coarse aggregate is within the range of aggregate properties used in concrete according to Indian Standards and can be used as a coarse aggregate. (Punit Malik, 2014).

Concrete having tiles can consequently be used similarly as conventional concrete (Tavakoli, 2013). His report also suggested that, compressive strength of concrete increased by 5.1% using a substitution of 10%. Compressive strength of cement using a replacement of 40% remained almost similar to that with 100% normal aggregate. Reduction in strength may have resulted after an increase in the flaky aggregate (Tavakoli, 2013).

Ay and Unal investigated the prospect of replacing cement with powdered waste ceramic tile in concrete. It was found that powdered waste ceramic tile had pozzolanic properties and it was possible to replace cement with 35% by weight of powdered waste ceramic tile (Ay and Unal, 2000).

Khaloo studied the use of crushed tile as a coarse aggregate in concrete. The crushed tile (coarse aggregate) had a much higher water absorption value and lower gravity compared to natural crushed stones. The test concrete was made with coarse aggregate; 100% crushed tile had a lesser density, higher compressive (+2%), flexural (+29%) and tensile (+70%) strengths (Khaloo, 1995).

Akhtaruzzaman and Hasnat studied the use of manually crushed clay bricks as 100% coarse aggregate. Mechanical and physical properties were determined from four grades of concrete. The crushed brick aggregate particles had a bulk specific gravity, unit weight and water absorption value of 1.93%, 953kg/m3and 11.2% respectively. The concrete cast had a compressive strength from 13.5 MPa to MPa and a unit weight between 2000kg/m3 and 2080 kg/m3. Comparing the properties of concrete with natural aggregates; modulus of elasticity was 30% lower, the unit weight was 17% less and the tensile strength was approximately 11% higher.

# CHAPTER THREE

# METHODOLOGY

## 3.1 MATERIALS, METHODS AND PROCEDURES

Generally, the materials used for the study included sand, crushed granite from quarry, ordinary Portland cement, potable water and waste ceramic tiles from construction sites and sales points. The crushed granite aggregate was partially replaced by waste ceramic aggregate in different percentages of (0, 10, 20, 30, and 40) as coarse aggregate for the experiment to produce various concrete mixes of C20 nominal strength at a constant water - cement ratio of 0.5.

Material tests and slump tests were conducted on the aggregates and fresh concrete to determine their physical properties and workability, respectively. Concrete cubes of size 150mm x 150mm x 150mm were then cast from the various mixes for compressive strength test on the 7th and 28th day. The test results were then compared to standard values given in texts while the specimens were weighed to determine the density of the various mixes.

The methods and procedures are elaborately presented below. The main highlights of the methodology were in accordance with the objectives of this research and will be discussed as we proceed, while the materials and procedures will be listed for each objective. The main research method was laboratory research, although experimental research design cannot be ignored. Samples of concrete mixes containing ceramic waste as fine aggregates was made and subjected to the appropriate tests to determine their properties. Certain properties of ceramic waste aggregates were also determined by laboratory tests as explained below:

i. Collection and crushing of waste ceramic waste to obtain fine aggregate.
ii. Sampling

iii. Grading of aggregates according to BS 882.

iv. To test for water absorption and specific gravity (density test) of the ceramic concrete.

v. Evaluation of the influence of ceramic replacement on other properties such as water absorption and durability.

vi. Evaluation of mix designs for the control mixes up to 50%; (100% natural fine aggregate sand, Class 20.)

vii. Conduct partial replacement of control fine aggregate (sand) with crushed ceramic waste fine aggregate.

viii. Establishing the properties of the cured concrete specimen at 7 days, 14 days and 28 days of curing.

The properties determined was:

a. Compressive strength
b. Flexural strength
c. Split tensile strength

## 3.2 SAMPLING AND COLLECTION OF WASTE CERAMIC

Crushed ceramic waste aggregate were obtained from manual crushing, followed by machine grinding, which was sampled using riffling method. In riffling method, the sample is split into two halves using a riffle box. This is a box with a number of parallel vertical divisions, alternate ones discharging to the left and to the right. The sample is discharged into the riffle box over its full width and the two halves are collected into the boxes at the bottom of the chutes on each side. One half is discarded and riffling of the other half is repeated until the sample is reduced to the desired size. They were tested to assess their engineering properties such as Gradation, Moisture content, Bulk Specific Gravity, Aggregate Impact Value and Los Angeles Abrasion value, in accordance with standards or specifications in the BS 882.

## 3.3 DETAILS OF TESTS CONDUCTED ON MATERIALS

Testing of the materials for the concrete was necessary as it had great impact on the outcome of the product. The following tests below were carried out on the materials:

### a. GRADUATION TEST

Sieve analysis was conducted on the fine and coarse aggregates to determine their particle size distribution in accordance with British Standards and tabulated in results. The organic matter test was also conducted on the fine aggregate as well using glass bottle and caustic soda in accordance with BS 1377.

### b. CONTENT TEST ON AGGREGATES

Water content test conforming to BS 812: Part 109: was conducted on the aggregates (in order to determine more accurately the quantity of water to be added to the mix to achieve required water cement ratio) at temperature of 105 ± 5°C for a period of 24 hours. The Moisture Content as expressed as percentage by dry mass was computed as shown in Equation 1:

$$\text{Moisture Content (\% dry mass)} = \left[\frac{M2-M3}{M3-M1}\right] \times 100 \text{ ......................... Eq. (3.1)}$$

Where:

M1 = weight of container

M2 = weight of container and wet material

M3 = weight of container and dried material

### c. AGGREGATE IMPACT VALUE TEST

The resistance of the aggregates to sudden impact or shock, which may differ from its resistance to gradually applied compressive load were determined as specified in the BS 882 using the impact machine. A measuring scale and a well-ventilated oven were also integral parts of the apparatus for the test. The cup was fixed firmly in position on the base of the machine with the test specimen placed in it. A total of 25 strokes of the tamping rod were made with adjusted hammer height of 380 ± 5 mm after which a total of 15 blows were given to the aggregates at intervals not less than 1sec. The aggregates were then removed and sieved on a 2.36mm sieve size. The percentage passing and retained were both weighed to the nearest 0.1g and recorded.

### d. LOSS ANGELES ABRASION TEST

Abrasion test was used to determine the toughness and abrasion characteristics of the aggregate using Los Angeles Abrasion test conforming to AASHTO to determine the quality and suitability of aggregate for the intended construction work. The test setup consisted of a set of sieves, mechanical component comprising a hollow steel cylinder with closed ends, standard steel balls, and the test coarse aggregate. By procedure, the specimens were placed in the abrasion test machine after which steel balls were added. The machine was rotated to a number of 500 revolutions at a speed of 33 revolutions per minute. The aggregates were then poured into the No. 12 sieve for the percentage passing and retained to be recorded. They were then dried in an oven and the percentage aggregate loss due to abrasion was calculated by finding the difference in weight between the percentage retained and the initial weight of the aggregate.

## 3.4 DATA COLLECTION

The primary source of data was from experiments done at the laboratories. Secondary data was also used. Two types of tests were carried out:

a. Tests to determine Aggregate properties.

b. Tests on concrete specimen.

### 3.4.1 TESTS TO DETERMINE AGGREGATE PROPERTIES

**a. Sieve Analysis:** This is an operation of dividing a sample of aggregate into fractions, each consisting of particles of the same size. Sieve analysis is used to determine particle size distribution.

**OBJECTIVE**

i. To determine the particle size distribution of specified aggregates.

ii. To draw grading curves for the aggregates specified.

**APPARATUS REQUIRED**

a. Balance accurate to 0.5g of mass of test sample.

b. Sample splitter

c. Test sieves as per BS 882.

d. Oven capable of maintaining constant temperature to within 5%.

e. Mechanism of shaking sieves. Chart for recoding results.

**PROCEDURE**

i. The test samples were dried to a constant mass by oven drying at about 105°C

ii. An approximate sample was taken from the original by riffling.

iii. The required sample was weighed out.

iv. The sieve of the largest mesh size was placed in the tray and the weighed sample put on to the sieve making sure the sieves are dry and clean before using them.

v. The sieve was shaken horizontally with a jerking motion in all directions for at least 2 minutes and until no more than a trace of a sample was passing, ensuring that all material passing fall into the tray.
vi. Any material retained on the sieve was weighed.
vii. The results were tabulated. The cumulative weigh passing each sieve was calculated as a percentage of the total sample to the nearest whole number.
viii. A grading curve for the sample was plotted in the grading chart.

## 3.5 WATER ABSORPTION TEST

Water absorption of concrete is an important parameter when considering the durability of concrete structures. For this study, the BS 1881- 122: served as a guide in conducting water absorption test. Concrete cube specimens were dried in an oven at 110ºC controlled temperature for 72 hours, and then allowed to cool for 24 hours in an airtight container. The weights of specimens were then recorded and immersed in water for 30 hours after which they were removed, wiped with cloth and weighed. The percentage of the weight of water absorbed to the dry weight of the sample was calculated as the water absorption for each specimen.

The absorption of the aggregate can influence such properties of concrete as the workability. Water absorption of aggregate can interfere with effective water-cement ratio if not checked. High level of absorption in aggregates reduces the workability of concrete (Hye-Yang Kim, 2011).

## 3.6 TESTS ON CONCRETE SPECIMEN

### a. SLUMP TEST

The slump test was carried out to measure the workability or consistency of fresh concrete, with higher slumps indicating greater fluidity.

**APPARATUS USED**

i. Slump cone (frustum of a cone)
ii. Tamping rod
iii. Base plate

**PROCEDURES**

i. Slump cone was filled with fresh concrete in three different layers.
ii. Each layer was tamped 25 times with the tamping rod.
iii. The cone was removed and the vertical settlement (slump) of the concrete was measured.

### b. COMPRESSIVE STRENGTH TEST

The compressive strength was conducted to measure the ability of concrete to resist bending forces. It is the most common performance measure used by the engineer in design of concrete structures. Compressive strength was measured by crushing 150 mm cubes on the universal testing machine. Compressive test is done as per (BS EN 12390: 2001).

**APPARATUS**

- Compression Testing Machine

**PROCEDURE**

i. The specimen was placed in the machine with the two cast faces in contact with the platens of the testing machine.
ii. The load was applied at a rate of 14N/mm2 until failure occurred.
iii. The compressive strength was recorded to the nearest 0.1N/mm.

c. **DENSITY AND WATER ABSORPTION TEST**

The density of the coarse aggregates being the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water, and the rate of water absorption of the coarse aggregates were determined in accordance with American Association of State Highway and Transportation Officials (AASHTO). Coarse aggregates that retained on the No. 4 (4.75 mm) sieve and free of all foreign particles as indicated for crushed granite and waste ceramic tiles above were used.

Specific gravity affects the volume of substitution of aggregates in concrete in order to produce equivalent mixture (A. E. B. CABRAL, 2008). Specific gravity is thus important in estimating the volume of components (cement, aggregate and water).

**d. TENSILE STRENGTH TEST BS 1881:117 – 1983**

The method adopted was the indirect tensile splitting test of cylindrical concrete specimens.

**APPARATUS**

i. Cylindrical mould (100mm diameter)
ii. Tensile testing machine.
iii. Poker vibrator.

**CASTING PROCEDURE**

- **a.** Concrete mixes were prepared and the fresh concrete cast in 100mm diameter moulds.
- **b.** Compaction was done in three layers using a poker vibrator to achieve the required compaction.
- **c.** The upper surfaces of the cylinders were then smoothened using a plasterer's float and the outside of the moulds were wiped clean.
- **d.** The specimens were then stored in an undisturbed environment for 24 hours, then cured in a curing tank for the required number of days.

**PROCEDURE**

i. The test specimens after curing for the required age was then removed and wiped.

ii. The specimens were then placed in the centering jig with loading pieces carefully positioned along the top and bottom of the plane of the loading system.

iii. The load was then applied and gradually increased at a normal rate of 0.02-0.04N/ mm2 and maintained until failure of the specimens.

iv. The maximum loads applied to each specimen were then recorded. The tensile splitting strength was computed as shown below;

$$M_{pa} = \frac{2F}{\pi \times l \times d} \quad \text{.......................................................} \text{ Eq. (3.2)}$$

Where;

*F* = Maximum load at failure (N)

*l* = Length of specimen.

*d* = Cross – sectional area of the specimen.

Tensile strength of normal concrete usually varies from 1/8th of compressive strength at early stages to about 1/20th later. Tensile strength is of crucial importance in resisting cracking due to changes in moisture content. Tensile tests are sometimes used for concrete roads and airfields.

# CHAPTER FOUR

# RESULTS AND DISCUSSION

## 4.1 FRESH CONCRETE

The replacement of coarse aggregate with ceramic tile waste does not have much effect on workability of concrete.

### a. SLUMP TEST OF CONCRETE

The workability of the various concrete mixes by the slump test conducted is illustrated in the Table below. It can be seen that the control mix of 0% ceramic waste aggregate replacement of granite had the highest slump of 61mm while the mix with 40% ceramic waste replacement of granite recorded the least value of 45mm. It can be seen that there was a general trend of reduction in the slump as the percentage of ceramic waste aggregate replacement for granite increased in the mix. This was probably due to increase in specific surface area as a result of the increase in the quantity of ceramic waste aggregate, thus requiring more water to lubricate the material surfaces and make the concrete workable. It could therefore be mentioned that the slump is inversely proportional to the quantity of ceramic waste aggregate replacement for granite in the concrete.

| Slump Value for Various Percentage Replacement | |
|---|---|
| Percentage Replacement | Slump Value (mm) |
| 0% | 61 |
| 10% | 58 |
| 20% | 52 |
| 30% | 48 |
| 40% | 45 |

**Table 4.1 Slump Value for Various Percentage Replacement**

## 4.2 HARDENED CONCRETE

### a. COMPRESSVE STENGTH OF CONCRETE

At first, the compressive strength of concrete improves as the ceramic tile powder is applied. However, it was considerably reduced as the Ceramic tile powder is applied further. The impacts of different rates of the compressive force are summed up in the table below. In this investigation, three samples were tried for every blend, and the normal powder is contrasted and the apparent C20 blend. The compressive force discoveries in table are seen at day 7, 14, and 28.

| COMPRESSVE STRENGTH OF CONCRETE RESULTS FOR 7 DAYS | | | | | | |
|---|---|---|---|---|---|---|
| S/N | Percentage Replacement | Weight (Kg) | Density (Kg/m$^3$) | Failure load (KN) | Compressive Strength (N/mm$^2$) | Average Compressive strength (N/mm$^2$) |
| 1 | 0% | 2.143 | 2143 | 195.670 | 19.6 | 18.2 |
| 2 | | 2.087 | 2087 | 157.341 | 15.7 | |
| 3 | | 2.245 | 2245 | 192.11 | 19.2 | |
| 4 | 10% | 2.212 | 2212 | 144.358 | 14.4 | 15.2 |
| 5 | | 2.169 | 2169 | 142.017 | 14.2 | |
| 6 | | 2.286 | 2286 | 168.517 | 16.9 | |
| 7 | 20% | 2.460 | 2460 | 181.690 | 18.2 | 13.3 |
| 8 | | 2.435 | 2435 | 121.569 | 12.2 | |
| 9 | | 2.501 | 2501 | 96.228 | 9.6 | |
| 10 | 30% | 2.486 | 2486 | 105.272 | 10.5 | 12.0 |
| 11 | | 2.626 | 2626 | 111.698 | 11.2 | |
| 12 | | 2.440 | 2440 | 141.948 | 14.2 | |
| 13 | 40% | 2.253 | 2253 | 76.446 | 7.6 | 9.7 |
| 14 | | 2.211 | 2211 | 125.946 | 12.6 | |
| 15 | | 2.215 | 2215 | 91.412 | 9.1 | |

**Table 4.2 Compressive strength of concrete results for 7 days**

| COMPRESSIVE STRENGTH OF CONCRETE RESULTS FOR 14 DAYS | | | | | | |
|---|---|---|---|---|---|---|
| S/N | Replacement % | Weight (Kg) | Density (Kg/m$^3$) | Failure load (KN) | Compressive Strength (N/mm$^2$) | Average Compressive strength (N/mm$^2$) |
| 1 | 0% | 2.147 | 2147 | 210.45 | 21.0 | 19.6 |
| 2 | | 2.065 | 2065 | 189.33 | 18.9 | |
| 3 | | 2.114 | 2114 | 187.92 | 18.8 | |
| 4 | 10% | 2.096 | 2096 | 142.338 | 14.2 | 16.7 |
| 5 | | 2.830 | 2830 | 191.127 | 19.1 | |
| 6 | | 2.209 | 2209 | 169.327 | 16.9 | |
| 7 | 20% | 2.424 | 2424 | 167.728 | 16.8 | 15.8 |
| 8 | | 2.347 | 2347 | 151.845 | 15.2 | |
| 9 | | 2.389 | 2389 | 153.193 | 15.3 | |
| 10 | 30% | 2.562 | 2562 | 132.443 | 13.2 | 12.5 |
| 11 | | 2.515 | 2515 | 106.303 | 10.6 | |
| 12 | | 2.510 | 2510 | 137.886 | 13.8 | |
| 13 | 40% | 2.213 | 2213 | 78.231 | 7.8 | 11.1 |
| 14 | | 2.192 | 2192 | 149.443 | 14.9 | |
| 15 | | 2.266 | 2266 | 106.914 | 10.7 | |

**Table 4.3 Compressive strength of concrete results for 14 days**

| COMPRESSVE STRENGTH OF CONCRETE RESULTS FOR 28 DAYS | | | | | | |
|---|---|---|---|---|---|---|
| S/N | Replacement % | Weight (Kg) | Density ($Kg/m^3$) | Failure load (KN) | Compressive Strength ($N/mm^2$) | Average Compressive strength ($N/mm^2$) |
| 1 | 0% | 2.174 | 2174 | 223.564 | 22.4 | 20.9 |
| 2 | | 2.201 | 2201 | 211.421 | 21.1 | |
| 3 | | 2.198 | 2198 | 193.127 | 19.3 | |
| 4 | 10% | 2.294 | 2294 | 183.863 | 18.4 | 20.3 |
| 5 | | 2.298 | 2298 | 195.104 | 19.5 | |
| 6 | | 2.293 | 2293 | 228.612 | 22.9 | |
| 7 | 20% | 2.597 | 2597 | 178.113 | 17.8 | 19.5 |
| 8 | | 2.591 | 2591 | 210.521 | 21.1 | |
| 9 | | 2.610 | 2610 | 196.158 | 19.6 | |
| 10 | 30% | 2.452 | 2452 | 111.624 | 11.2 | 15.4 |
| 11 | | 2.399 | 2399 | 158.395 | 15.8 | |
| 12 | | 2.572 | 2572 | 191.831 | 19.2 | |
| 13 | 40% | 2.312 | 2312 | 93.925 | 9.4 | 12.4 |
| 14 | | 2.283 | 2283 | 155.270 | 15.5 | |
| 15 | | 2.407 | 2407 | 123.270 | 12.3 | |

**Table 4.4 Compressive strength of concrete results for 28 days**

### b. FLEXURAL STRENGTH OF CONCRETE

The cubic specimens of ordinary concrete and tile wastes concrete were tested for flexural strength and the results are obtained as in the Chart below. Flexural strength is tested to resistance against failure in bending. From the chart, it is clear that flexural strength of concrete is highest at 0% and then decreases for 10%, 20%, 30% and 40% replacement for 28 days testing.

| FLEXURAL STRENGTH TEST RESULTS AFTER 28 DAYS | | | | | |
|---|---|---|---|---|---|
| **S/N** | **Percentage replacement** | **Mass (Kg)** | **Failure Load (KN)** | **Flexural Strength ($N/mm^2$)** | **Average flexural strength ($N/mm^2$)** |
| 1 | 0% | 11.431 | 9.87 | 3.948 | 3.856 |
| 2 | | 11.875 | 10.14 | 4.056 | |
| 3 | | 12.073 | 8.91 | 3.564 | |
| 4 | 10% | 12.141 | 9.43 | 3.772 | 3.292 |
| 5 | | 12.312 | 7.54 | 3.016 | |
| 6 | | 11.567 | 7.72 | 3.088 | |
| 7 | 20% | 11.830 | 6.49 | 2.596 | 3.067 |
| 8 | | 12.221 | 8.37 | 3.348 | |
| 9 | | 11.792 | 8.14 | 3.256 | |
| 10 | 30% | 12.330 | 7.11 | 2.844 | 2.819 |
| 11 | | 11.712 | 6.18 | 2.472 | |
| 12 | | 11.604 | 7.85 | 3.140 | |
| 13 | 40% | 11.433 | 5.38 | 2.152 | 2.361 |
| 14 | | 11.615 | 6.46 | 2.584 | |
| 15 | | 12.011 | 4.97 | 1.988 | |

**Table 4.5 Flexural strength test results after 28 days**

For beam; $\sigma\ (flexural\ strength) = \frac{PL}{bd^2}$ ……………….……….. Eq (4.1)

Where;

P = Failure load (convert to N)

L = Distance between two supports (400mm)

b = Breadth of beam (100mm)

d = Depth of beam (100mm)

**c. SPLIT TENSILE STRENGTH**

The cylindrical specimens of ordinary concrete, and ceramic waste concrete were tested for split tensile strength of hardened concrete at the age of 28 days. The test result shown in table below revealed that the ceramic waste aggregate of different proportions decreased, when compared to normal convention concrete.

$M_{pa} = \frac{2F}{\pi DL}$ ………………………………………….. Eq (4.2)

Where;

F = Failure load [convert to N]

D = Diameter of circular base [150mm]

L = Length of curved lateral surface [300mm]

| SPLIT TENSILE STRENGTH RESULTS AFTER 28 DAYS | | | | | |
|---|---|---|---|---|---|
| S/N | Percentage Replacement | Mass (kg) | Failure Load (KN) | Split Tensile Strength | Average Split Tensile Strength |
| 1 | 0% | 11.961 | 210.18 | 2.973 | 2.874 |
| 2 | | 12.932 | 198.76 | 2.812 | |
| 3 | | 12.812 | 200.49 | 2.836 | |
| 4 | 10% | 12.055 | 152.11 | 2.152 | 2.526 |
| 5 | | 12.751 | 199.39 | 2.821 | |
| 6 | | 11.833 | 184.17 | 2.605 | |
| 7 | 20% | 11.952 | 171.05 | 2.420 | 2.371 |
| 8 | | 12.570 | 173.42 | 2.453 | |
| 9 | | 12.684 | 158.34 | 2.240 | |
| 10 | 30% | 11.417 | 152.13 | 2.152 | 2.183 |
| 11 | | 11.913 | 166.94 | 2.362 | |
| 12 | | 12.844 | 143.85 | 2.035 | |
| 13 | 40% | 12.766 | 130.12 | 1.841 | 1.746 |
| 14 | | 11.935 | 121.77 | 1.723 | |
| 15 | | 11.871 | 118.43 | 1.675 | |

**Table 4.6 Split tensile strength test results after 28days**

## 4.3 WATER CONTENT

Water content test was initially conducted on the fine and coarse aggregates to ascertain the quantity of moisture stored in the materials. The values from the tests are indicated to be 0.6%, 0.09% and 1.2% for crushed granite, ceramic waste aggregate, and sand respectively. The ceramic waste aggregate had the least moisture content while the sand recorded the highest. This might be due to the fact that the glazy/polished surfaces of the ceramic tiles did not allow easy penetration of water. These moisture content values were particularly necessary as they were considered in determining the quantity of water required for the concrete mix.

## 4.4 WATER ABSORPTION OF CONCRETE

Water absorption was determined by measuring the increase in mass as a percentage of dry mass. It was observed that the percentage water absorption increased from 0% to 30%, it then dropped at 40% ceramic waste replacement of granite specimen. The increase in water absorption was probably due to relatively porous nature of the unpolished side of the ceramic waste as compared to the granite. It is therefore advised that coarse aggregate replacement must not exceed 20% since there was not much significant increase in water absorption up to this limit compared to the control.

| S/N | % Replacement | Dry weight | Saturated weight after 24hrs | % of water absorbed | Average % of water absorbed |
|---|---|---|---|---|---|
| 1 | 0% | 2.435 | 2.438 | 0.123 | 0.547 |
| 2 | | 2.493 | 2.517 | 0.963 | |
| 3 | | 2.519 | 2.533 | 0.556 | |
| 4 | 10% | 2.492 | 2.514 | 0.883 | 0.826 |
| 5 | | 2.465 | 2.487 | 0.974 | |
| 6 | | 2.417 | 2.432 | 0.621 | |
| 7 | 20% | 2.455 | 2.481 | 1.060 | 0.994 |
| 8 | | 2.440 | 2.465 | 1.025 | |
| 9 | | 2.338 | 2.359 | 0.898 | |
| 10 | 30% | 2.534 | 2.563 | 1.144 | 1.256 |
| 11 | | 2.579 | 2.601 | 0.853 | |
| 12 | | 2.371 | 2.413 | 1.771 | |
| 13 | 40% | 2.428 | 2.460 | 1.318 | 1.152 |
| 14 | | 2.527 | 2.543 | 0.633 | |
| 15 | | 2.527 | 2.565 | 1.504 | |

**Table 4.7 Water absorption percentage obtained after 24hrs of immersion of concrete cubes with ceramic tiles required replacement of 0%, 10%, 20%, 30% and 40%**

By formula:

% of water absorbed = $\frac{saturated\ weight - dry\ weight}{dry\ weight} \times 100$ ………………..……Eq (4.3)

**4.5 DENSTY OF CONCRETE**

A trend of reduction was seen in the determination of the densities of the concrete product produced in the study for both 7 and 28 days curing. The density decreases with increase percentage ceramic waste replacement, that is from 0% to 40%, for granite in the concrete produced. This could be as a result of the weight difference between granite and ceramic aggregates.

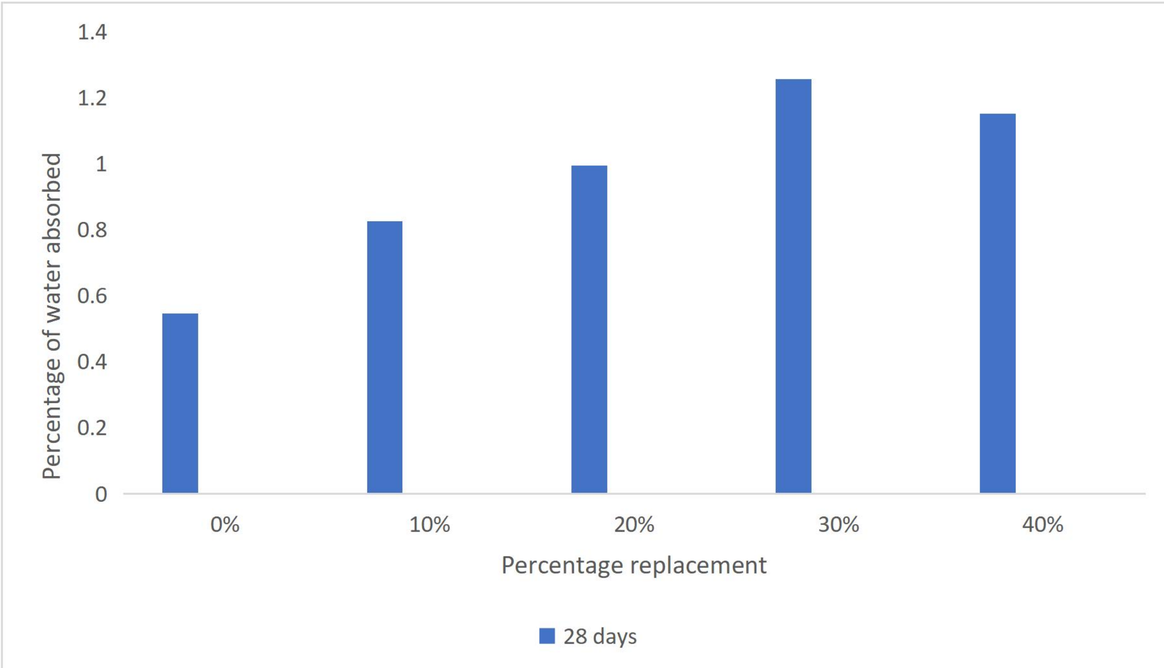


**Figure 4.1 Relationship between percentage of water absorbed and the percentage replacement**

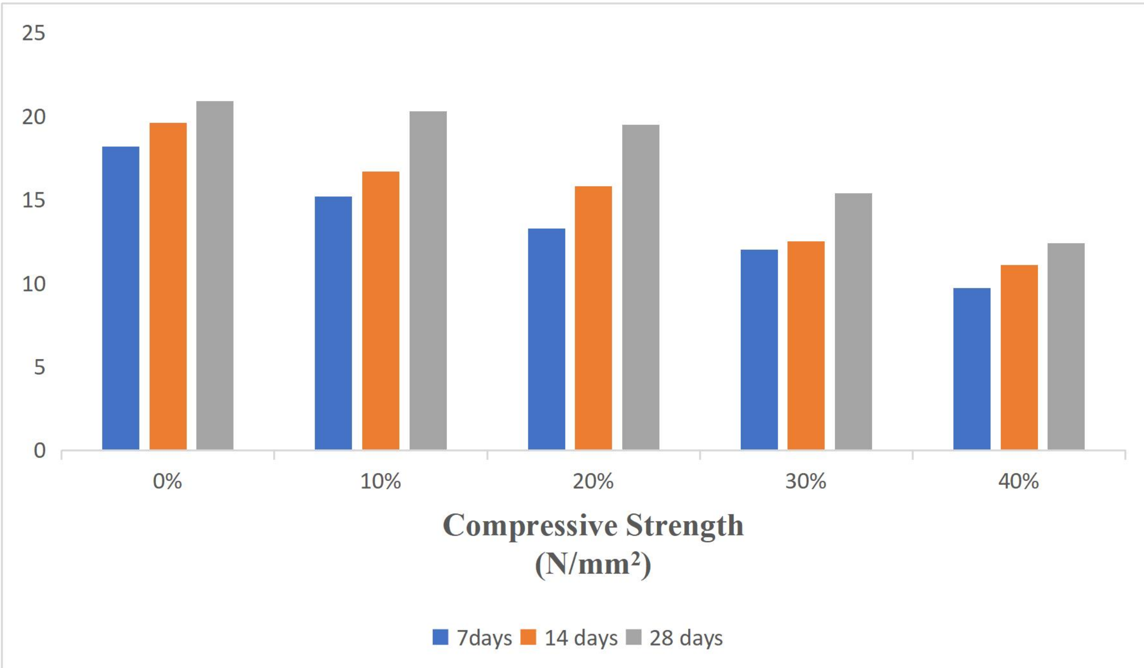


**Figure 4.2 Relationship between compressive strength and the replacement of coarse aggregate with ceramic tile waste**

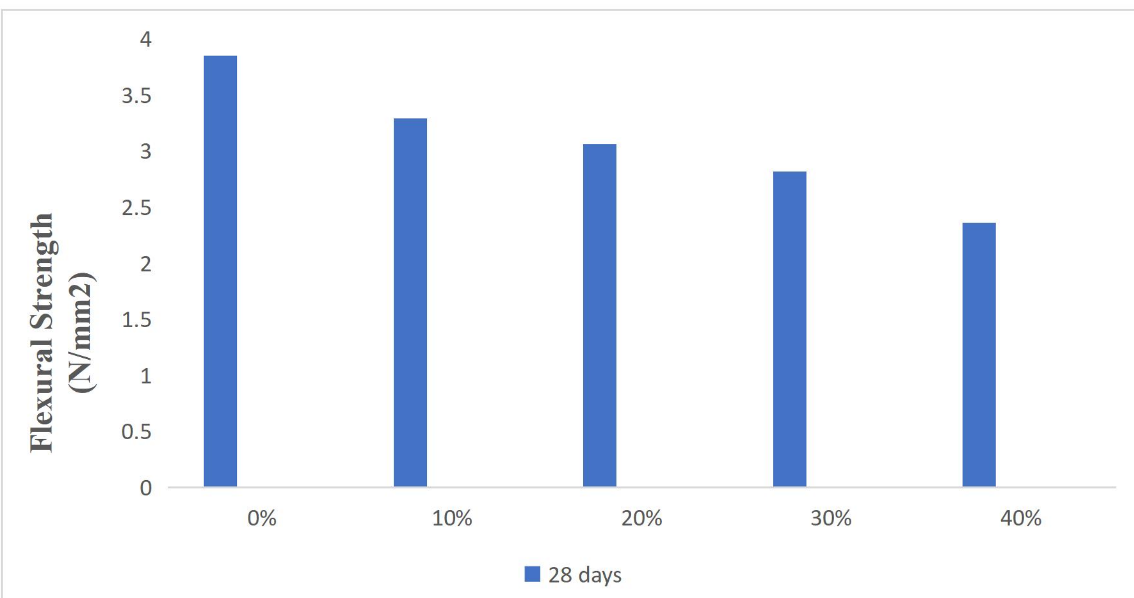


**Figure 4.3 Relationship between flexural strength and the replacement of coarse aggregate with ceramic tile waste**

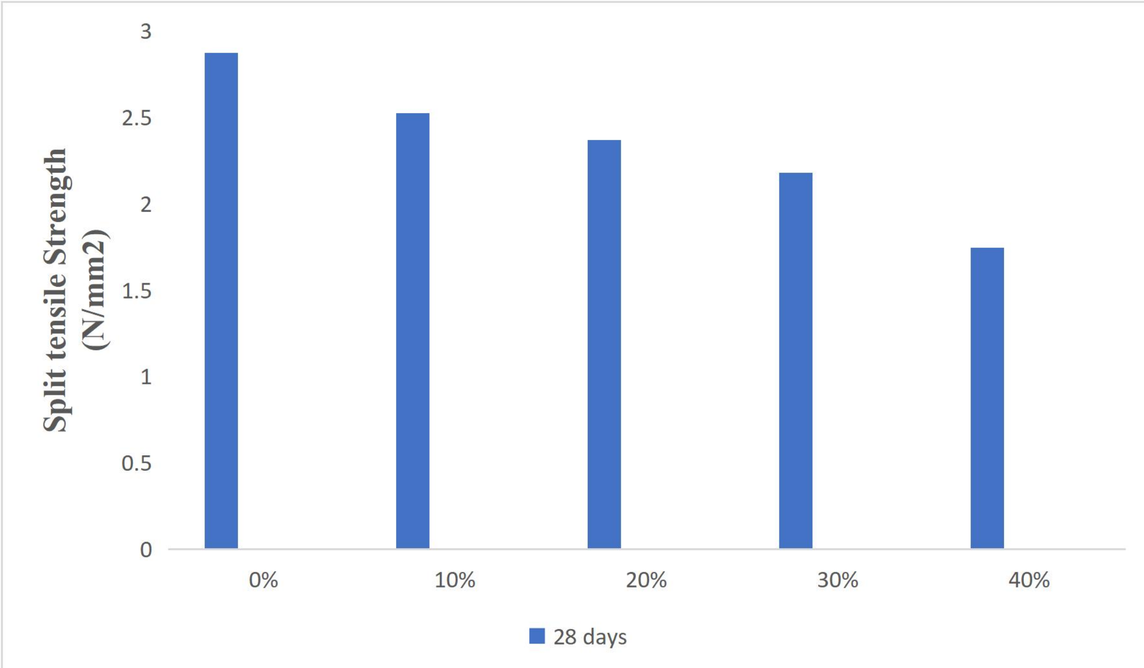


**Figure 4.4 Relationship between split tensile strength and the replacement of coarse aggregate with ceramic tile waste**

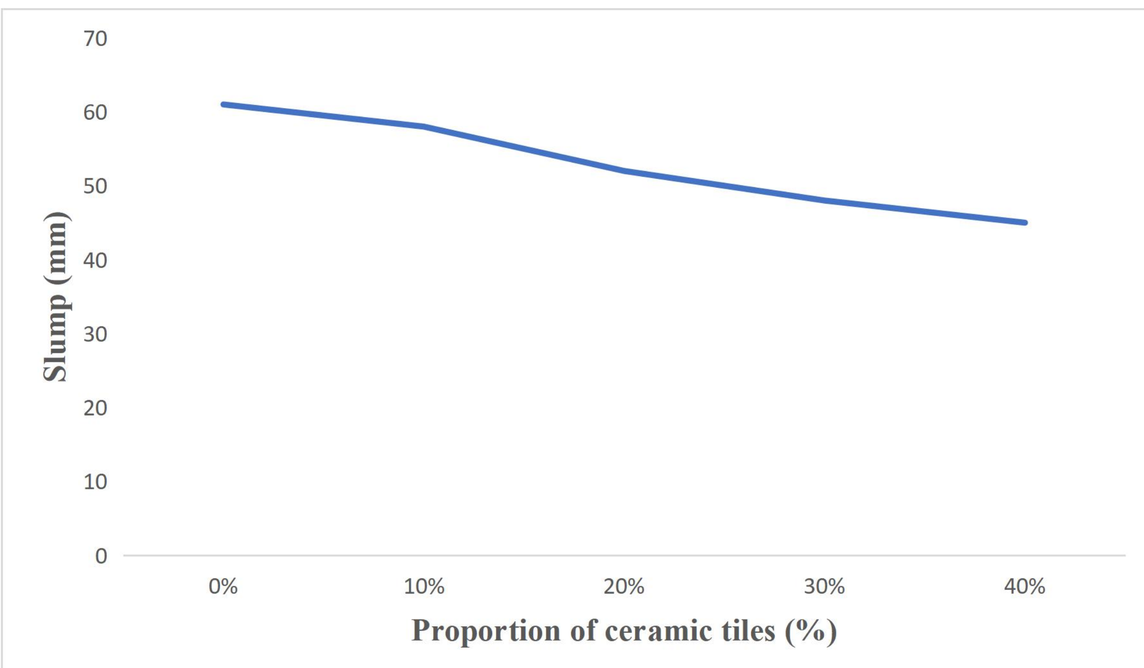


**Figure 4.5 Slump of concrete with varying percentage of ceramic waste**

# CHAPTER FIVE

# CONCLUSSION AND RECOMMENDATIONS

## 5.1 CONCLUSSION

The objectives and aim of the project were met. The aim of this investigation was the utilization of tiles collected from industries in concrete as coarse aggregate and the strength characteristics of tile waste as replacement of coarse aggregate. After experimental methods employed, it was concluded that:

**i.** Replacement of coarse aggregate with ceramic tile waste has not much effect on the workability of concrete.

**ii.** Crushed granite had better resistance to Impact load compared to ceramic waste aggregate. Nonetheless, the Impact values obtained for the aggregate is below acceptable maximum limit of 35% and 30% respectively for structural concrete.

**iii.** Ceramic wastes from the construction sites and ceramic manufacturing industries could be recycled by breaking them into various coarse aggregate sizes and used in concrete mixes. However, a maximum content of 20% ceramic waste aggregate replacement in a mix is ideal to produce the required strength and durability of structural concrete.

**iv.** The compressive strength of concrete reduced with the increase in percentage replacement. However, the reduction rates were significantly low for all the ages and percentage replacement. Using up to 100% will not produce a weak concrete.

**v.** Flexural strength of concrete mixes, up to 10% replacement with tile waste, is greater than conventional concrete mix.

**vi.** Split tensile strength of concrete mixes, up to 20% replacement with sanitary ceramic waste, is greater than conventional concrete mix.

vii. The use of tile powder and its use for sustainable building industry growth is the most effective approach and also tackles the high value use of such waste.

## 5.2 RECOMMENDATIONS

From the series of laboratory tests performed and results obtained, it is hereby recommended that replacement of conventional aggregates with ceramic tile waste n production of concrete be limited to 40%. However, production of concrete with higher percentage of ceramic tile waste does not produce weak concrete but increases the water absorption.

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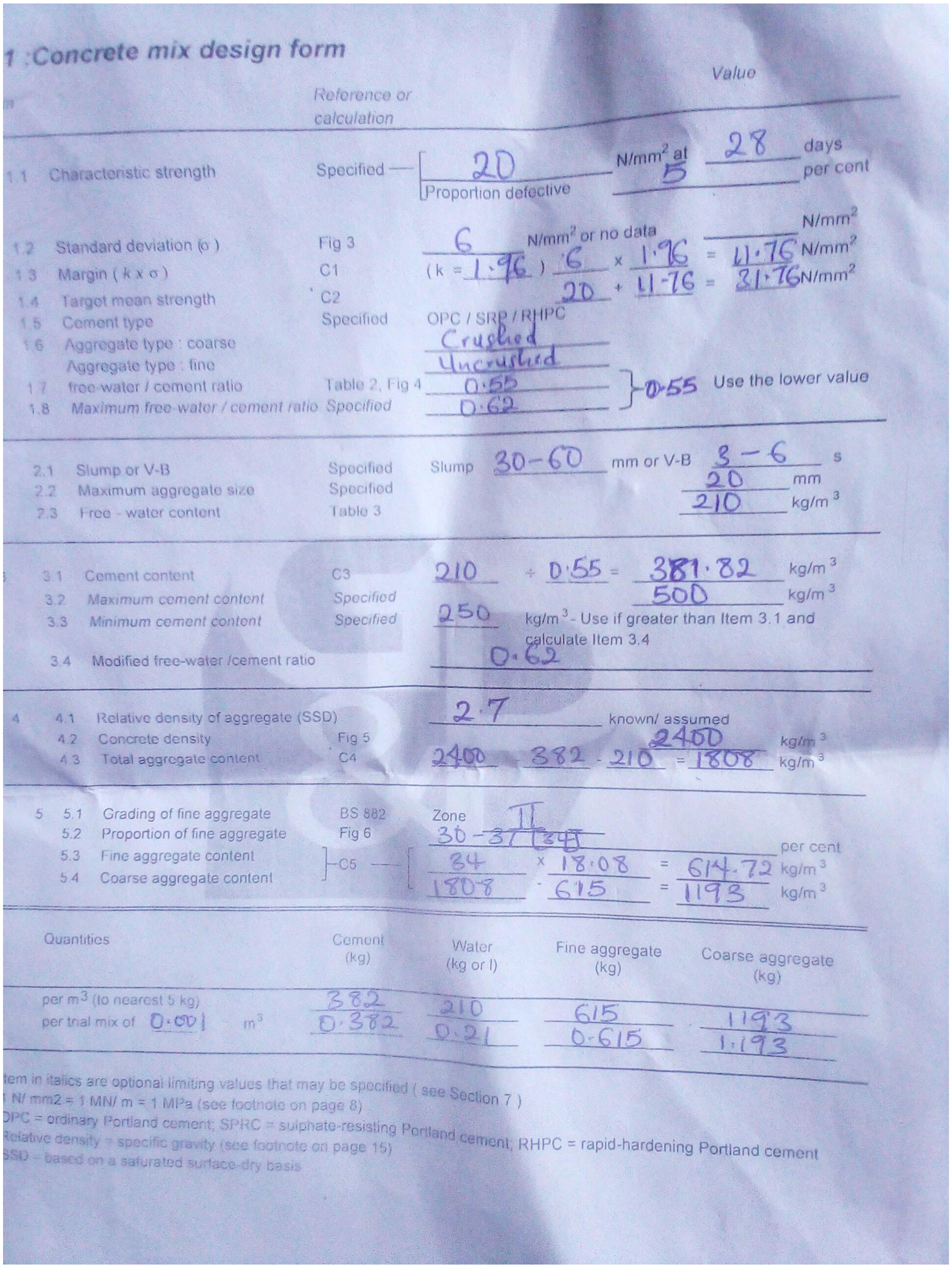
**APPENDIX**



1 :Concrete mix design form

| Item | Reference or calculation | Value |
|---|---|---|
| 1.1 Characteristic strength | Specified | 20 N/mm² at 28 days; Proportion defective 5 per cent |
| 1.2 Standard deviation (σ) | Fig 3 | 6 N/mm² or no data ___ N/mm² |
| 1.3 Margin (k x σ) | C1 | (k = 1.96) 6 x 1.96 = 11.76 N/mm² |
| 1.4 Target mean strength | C2 | 20 + 11.76 = 31.76 N/mm² |
| 1.5 Cement type | Specified | OPC / SRP / RHPC |
| 1.6 Aggregate type : coarse | | Crushed |
| Aggregate type : fine | | Uncrushed |
| 1.7 Free-water / cement ratio | Table 2, Fig 4 | 0.55 } 0.55 Use the lower value |
| 1.8 *Maximum free-water / cement ratio* | *Specified* | 0.62 |
| 2.1 Slump or V-B | Specified | Slump 30-60 mm or V-B 3 - 6 s |
| 2.2 Maximum aggregate size | Specified | 20 mm |
| 2.3 Free - water content | Table 3 | 210 kg/m³ |
| 3.1 Cement content | C3 | 210 ÷ 0.55 = 381.82 kg/m³ |
| 3.2 *Maximum cement content* | *Specified* | 500 kg/m³ |
| 3.3 *Minimum cement content* | *Specified* | 250 kg/m³ - Use if greater than Item 3.1 and calculate Item 3.4 |
| 3.4 Modified free-water /cement ratio | | 0.62 |
| 4.1 Relative density of aggregate (SSD) | | 2.7 known/ assumed |
| 4.2 Concrete density | Fig 5 | 2400 kg/m³ |
| 4.3 Total aggregate content | C4 | 2400 - 382 - 210 = 1808 kg/m³ |
| 5.1 Grading of fine aggregate | BS 882 | Zone II |
| 5.2 Proportion of fine aggregate | Fig 6 | 30 - 37 (34) per cent |
| 5.3 Fine aggregate content | C5 | 34 x 18.08 = 614.72 kg/m³ |
| 5.4 Coarse aggregate content | C5 | 1808 - 615 = 1193 kg/m³ |

| Quantities | Cement (kg) | Water (kg or l) | Fine aggregate (kg) | Coarse aggregate (kg) |
|---|---|---|---|---|
| per m³ (to nearest 5 kg) | 382 | 210 | 615 | 1193 |
| per trial mix of 0.001 m³ | 0.382 | 0.21 | 0.615 | 1.193 |

Items in italics are optional limiting values that may be specified (see Section 7)
1 N/ mm2 = 1 MN/ m = 1 MPa (see footnote on page 8)
OPC = ordinary Portland cement; SPRC = sulphate-resisting Portland cement, RHPC = rapid-hardening Portland cement
Relative density = specific gravity (see footnote on page 15)
SSD = based on a saturated surface-dry basis

Plate 1: Mix design chart


**Plate 2: Compressive strength test in the lab**

**Plate 3: Concrete mixing with partial ceramic tile replacement**


**Plate 4: Concrete cube weighing**


**Plate 5: Concrete mix vibration**