AN ASSESSMENT OF THE PROPERTIES OF CONCRETE MADE WITH CERAMIC WASTE AS AGGREGATE

BY

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DEPARTMENT OF BUILDING
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DECLARATION

I declare that the work in the thesis entitled "An assessment of the properties of concrete made with ceramic waste as aggregate" has been done by me in the Department of Building under supervision of Prof. M. M. Garba and Mallam M. I. Khalil. The information provided from the literature has been acknowledged in the work and the list of references provided. No part of this thesis has been submitted for any degree award in any university or institution.

……	……..	……..
Name of Student	Signature	Date

CERTIFICATION

This thesis entitled "An assessment of the properties of concrete made with ceramic waste as aggregate" by Mohammed Kabir, meets the regulation governing the award of degree (M. Sc. Construction Technology) Ahmad Bello University, Zaria, and is approved for its contribution to knowledged.

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DEDICATION

My dedication goes to my parents, in person of (Mallam Mohammed Umar and Mallama Fatsuma Mohammad) and my uncles Alhaji Ibrahim Yamta, Alhaji Ahmad Umar and Bukar Umar and family members for their support and guidance.

AKNWOLEDGEMENT

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ABSTRACT

The quantity of ceramic waste tile in Nigeria has been on the increase without consideration for potential reused or recycling. This increases the risk to public health due to the scarcity of land area. The growing problem can be solved if new disposal option other than landfill can be found. Continuous dependence on conventional materials for concrete is also leading to scarcity of its materials resulting to increase in construction cost. This research was carried out to establish the suitability of ceramic waste tile as aggregate for concrete production. Ceramic waste tile originate from broken, scrap and leftover tiles. The replacement proportion was 100% for both fine and coarse natural aggregates. A total number of 100 cubes were cast using nominal mix ratio of 1:2:4 with water cement ratio of 0.55 and tested for compressive and split tensile strength at 7, 14, 28 and 56 days. Abrasion resistance and water absorption tests were carried out at 28 days of curing age. The results showed that at 28 days the compressive strength was 22.27N/mm^2 and 19.46N/mm^2, and split tensile strength of 2.94N/mm^2 and 1.94N/mm^2 for ceramic waste tile concrete and that of conventional concrete. This research concludes that the ceramic waste tile concrete has a higher strength and durability than conventional concrete and also recommends that the ceramic waste tile can be used as an alternative construction material for fine and coarse aggregate.

TABLE OF CONTENTS

Chapter **Page**

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDIX

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

It has been estimated that about 30% of the daily production tile in the ceramic industry goes to waste (Senthamarai and Devadas, 2005). This waste is not recycled in any form at present. 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 its disposal. Meanwhile, conventional crush stone aggregate reserve are depleting fast, particularly in some desert region of the world (Senthamarai and Manoharan, 2005). The need to develop concrete with non-conventional aggregate is urgent for environmental and as well as economic reasons.

Cement and aggregate, which are important constituents used in concrete production, are the vital materials needed for the construction industry. This inevitably led to a continuous and increase demand of natural materials used for their production. Parallel to the need for the utilization of the natural resources develop a growing concern to the environment and need to preserve natural resources, such as aggregate, by recycling alternative waste materials. Ceramic tiles are important construction materials used in almost all buildings. The production of these tiles normally starts from raw material, grinding and mixing, granulating by spray drying, pressing, firing and/or polishing and glazing (Wattanasiriwech et al, 2009).

Ceramic waste can be transformed into useful coarse aggregate. The properties of ceramic waste coarse aggregate are well within the range of the value specify for concrete making aggregates. The properties of ceramic waste coarse aggregate concrete are not significantly different from those of conventional concrete. According to (Binnici, 2007) the use of ceramic waste coarse aggregate concrete has increased because it has various advantages over

other cementitious materials. Homogeneous ceramic tiles waste can be used as a replacement to natural crushed stones, as their properties are similar to the natural coarse aggregates (Mashitah et al, 2008). Recycled concrete obtained through partial substitution of natural coarse aggregate is suitable for structural purposes (Medina et al, 2009). Concrete with ceramic waste powder has a minor strength loss but possess increased durability performance because of its pozzolanic properties. As for the replacement of traditional coarse aggregates by ceramic coarse aggregates, the results are promising but they underperform slightly in water absorption meaning that the replacement of traditional sand by ceramic sand is a better option (Pacheco and Jalali, 2010). Ceramic scrap can be partially used to replace conventional coarse aggregates (10% and 20%), without affecting its structural performance (Reddy and Reddy, 2007).

Tavakoli et al (2013) shows that using tile as a coarse aggregate there is no reduction in the strength of concrete, but also increase the compressive strength of it up to 30% and in higher percent (up to 40%) bear no negative impact on compressive strength. The strength of the samples which include tile has been reported to be very similar to each other. Khaloo (1995) investigated the use of crushed tiles as a source of coarse aggregate in concrete. The research shows that crushed tile had a lower density and a higher water absorption value compared to those of natural crushed stone. The concrete made with 100% crushed tile as the coarse aggregate had a lower density and higher compressive (+2%), tensile (+70%) and flexural (+29%) strengths. Kanaka et al (1992) Found that crushed ceramic aggregate can be used to produce lightweight concrete, without affecting the strength.

Brito (2005) suggested that ceramic tile aggregates can be used in elements in which the primary requirement is not compressive strength. However, it can be used in members

wherein tensile strength and abrasion resistance are of primary importance, such as for concrete pavement slabs.

1.2 Statement of the Research Problem

Concrete is the most widely construction material. This has led to an increase in the rates of the materials used to make concrete that is aggregates and cement. The extensive use of concrete has led to high consumption of aggregates. Continuous usage of this non-renewable resource would cause the depletion of this natural aggregate for the use of future generation. The generation of ceramic waste tile continued to increase during construction and lots of the ceramic waste tile goes to waste, scrap and leftover. The waste has been dump and stockpiled at landfill, thus causing disposal problem in large quantity since the waste are pilling every day. Hence, these ceramic waste tile has been used either fine or coarse aggregate. However, the combined use of tile as fine and coarse aggregate to wholly replace conventional aggregates in concrete has not been studied. From the standpoint of sustainability, use of recycled materials as aggregates provides several advantages. Landfill space used for disposal is decreased, and existing natural aggregate sources are not as quickly depleted.

In addition with the global economic recession couple with the market inflatationary trends the constituent materials used for structures had led to a very high cost of construction. Using ceramic waste tile as aggregate in production of concrete materials would reduce the environmental problem by utilizing the waste and also reduces the cost of the concrete. Reclaiming land degraded by quarrying is also an expensive process and takes time to salvage its glory.

1.3 Justification for the Study

The experimental study could establish the suitability of ceramic waste aggregate for concrete production. Since it is clearly known and understood that the rising cost of concrete production limits the use of concrete, a study on the alternative readily available materials (like ceramic waste aggregates) can lead to cheaper concrete. Also from environmental point of view, recycling of these wastes would help in the protection of environment against excessive exploitation of granite and the accompanying environmental degradation. The result of this research may lead to the use of ceramic waste tiles aggregate instead of sand and crushed granite for production of concrete.

1.4 Aim and Objectives

1.4.1 Aim

The aim of this research is to assess the properties of concrete made with ceramic waste tiles as fine and coarse aggregates, this is with a view to establishing its suitability for use in the production of concrete.

1.4.2 Objectives

The stated aim was pursued through the following objectives:

i. To assess the physical and mechanical properties of ceramic waste aggregate

ii. To establish a suitable mix ratio for the production of concrete with ceramic waste aggregate

iii. To assess the physical and mechanical properties of ceramic waste aggregate concrete.

iv. To compare the result of ceramic waste tile and that of conventional concrete

1.5 Research Design

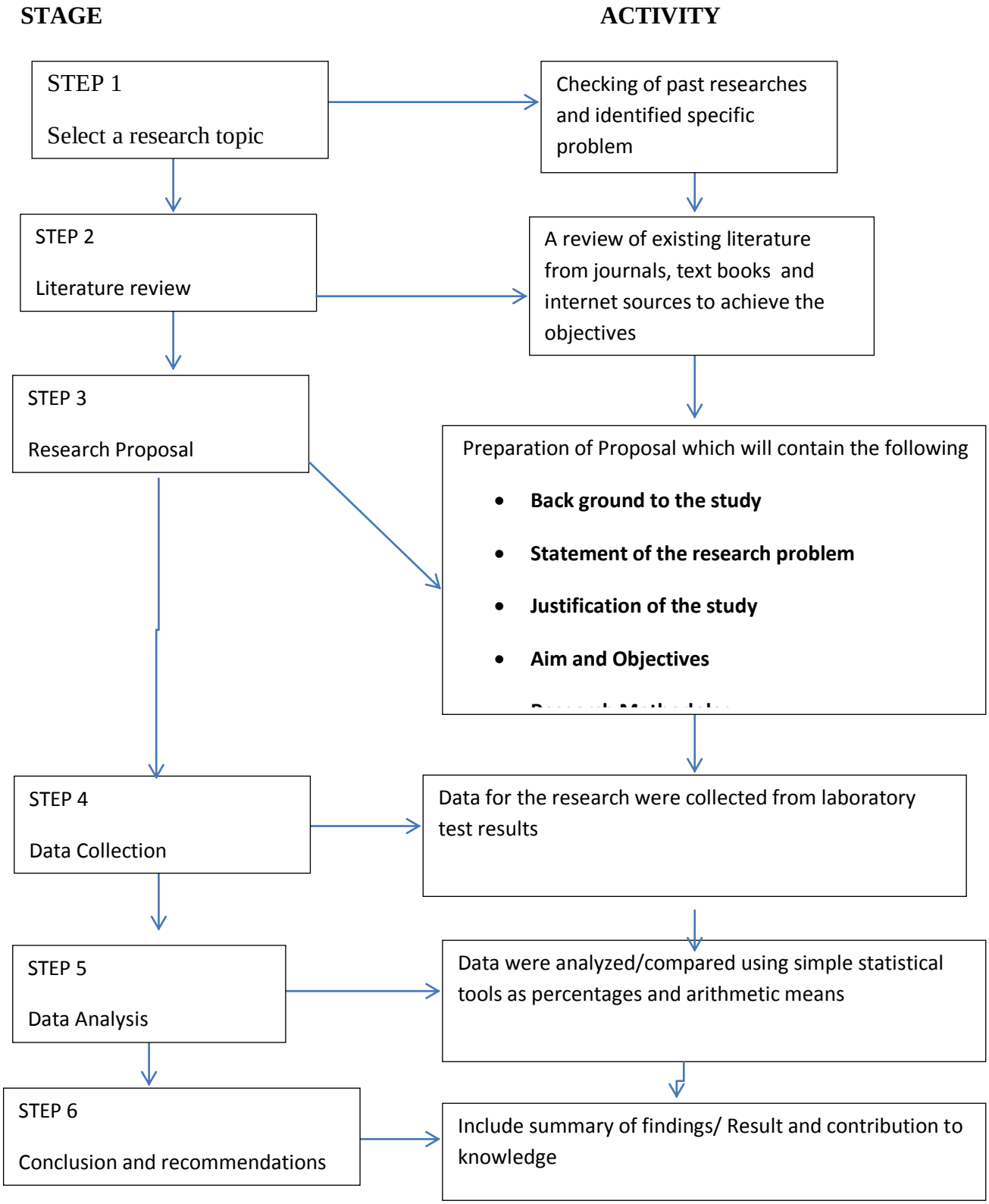


Figure 1.0 Re*search Design*

1.6 Scope and Delimitations

1.6.1 Scope

The study is restricted to laboratory experimental tests on the physical and mechanical properties such as tensile strength, compressive strength, abrasion resistance and water absorption test.

1.6.2 Delimitations

The research would not cover areas such as flexural strength, porosity, and permeability tests. It was tested on areas specified.

CHAPTER TWO

2.0 LITERATURE REVIEW

Relevant literatures were reviewed from different text books, journals, conferences seminars published and unpublished research works, lecture notes, etc. So as to articulate the existing knowledge to utilize the use of ceramic waste tiles in concrete production.

2.1 Aggregate

The term aggregate is used broadly by the construction industry to refer to natural mineral materials used for various types of construction. It consists of large chunks of materials in a concrete mix which are generally sand, gravel, or crushed rocks and such as limestone or granite. According to larfage group (2013) it noted that aggregates, such as crushed rock, manufactured sand, natural sand and gravel are the most used materials in the world after water, which almost 25 billion tons of aggregate are used per year, at an average of 4 tons per person.

Robinson et al (2004) describe the term aggregates as an industrial commodity in term of sand, gravel, and crushed rock materials, in their natural or processed state, that are used to provide bulk, strength, and wear resistance in construction applications. (Barkdale, 2000; Robinson et al, 2004) In the U.S., aggregates are primarily used in the production of Portland cement concrete, asphalt pavement, and as structural fill in the construction and maintenance of roads and buildings (Tepordei, 1999). In Europe, the word aggregate is also used to describe recycled concrete, bricks and ceramics which are often crushed and used as fill for civil engineering projects. More recently, these recycled aggregates have begun to be used in Europe for the production of new concrete (Weil et al. 2006).

Between 70 to 80 percent of the total volume of concrete is occupied by aggregate, (Alexander and Sydney, 2005) there are two types of aggregates namely fine and coarse

aggregates. Fine aggregate is generally natural sand and is graded from particles 5mm in size to the finest particles but excluding dust. While, coarse aggregate is natural gravel or crushed stone usually larger than 5mm and usually less than 16mm in ordinary structure.

2.1.1 Materials for Aggregates

According to Garba (2014) aggregate materials are used in concrete to increase its strength, volume and durability, reduce creep, reduce shrinkage and reduce overall cost, thermal properties and impact sound, impact density, increase chemical resistance. The materials used as aggregate include: palm kennel shells, pumice, crush rock, recycle concrete, gravel, scrap iron, lead, iron shots, barites, crush burnt bricks, etc. Almost any available material that met some basic requirement can be used as aggregate for concrete. For aggregate to be used in normal structural concrete the following characteristics should be considered; cleanness, hardness, cost, chemical inertness, availability in required sizes, and availability in good shape, availability required grading and availability in good surface textures.

The characteristics for aggregate are cleanness, grading, hardness and shape. While the principal characteristics are important since they affect both the concrete and mortar like cost, workability, strength and durability.

2.1.2 Grading of Aggregates

Grading determines the paste requirement for a workable concrete since the amount of voids among aggregate particles requires the same amount of cement paste to fill out in the concrete mixture. To obtain a grading curve for an aggregate, sieve analysis has to be conducted. Aggregate comprise about 55 percent of the volume of mortar and about 85 percent volume of mass concrete. Mortar contains aggregate size of 4.75mm and concrete contains boulder up to a maximum size of 150mm.

Aggregates are available either as divided or all-in aggregate. The one that comes in separate sizes is divided aggregate. An all-in aggregate contains all the various sizes of particles in one sample of aggregate and if the grading is good enough, it can be used to produce concrete.

2.1.3 Classification of Aggregate

Mineral aggregate was used as inert filler in cement concrete. The aggregate is not an inert filler and its physical, thermal and chemical properties influence the performance of the concrete to a great extent. The aggregate is cheaper than cement and thus it is cheaper to use as much quantity of aggregate and as little of cement as possible, but economy alone is not the reason for using aggregate in the concrete.

a. Based on Source

I. **Natural Aggregate:** These are obtained by crushing from quarries of igneous, sedimentary or metamorphic rocks. Gravels and sand reduced to their present size by the natural agencies also fall in this category. The most widely used aggregate are from igneous origin. Aggregates obtained from pits or dredged from river, creek or sea are most often not clean enough or well graded to suit the quality requirement (Duggal, 2008).

There are various rock types when crushed are suitable for used as aggregates. These include;

1. Limestone: Are sedimentary rocks chiefly composed of calcium carbonate. The harder and denser types particularly the carboniferous types are suitable for concrete. Less hard types are unsatisfactory.

2. Igneous rocks: The most common are the granites, basalts apliteand gabbros. Granitic aggregates are commonly used because they are hard, tough and dense and are excellent in bonding with cement (Gupta and Gupta, 2012).

3. Metamorphic rocks: They have variable characteristics. Marbles and quartzite's are usually massive, dense and adequately tough thus provide good aggregates. However schist's and slates are often thinly laminated and are therefore unsuitable.

Other rocks such as shale, sandstones etc. are rarely available. Shale's 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.

Plate 1: Natural Coarse Aggregate

Source: (Ishak, 2009)

II. **Artificial Aggregates:** These are manufactured mainly from industrial by – products, waste materials or sometimes natural materials. However plants for manufacturing artificial aggregate are now in use. These kinds of aggregates are normally used in lightweight or heavy weight concrete or when to use up some industrial by-product beneficially. They are mainly lightweight aggregates. According to Gupta and Gupta

(2012) some artificial aggregates are the byproduct of an unrelated industrial process as cinder, blast furnace slag, sintered glass aggregate etc. Duggal (2008) broken bricks, blast furnace slag and synthetic aggregates are artificial aggregates. Broken bricks known as brick bats are suitable for mass concreting, for example, in foundation bases. They are not used for reinforced concrete works. Blast furnance slag aggregate is obtained from slow cooling of the slag followed by crushing. The dense and strong particles as obtained are used for making precast concrete products. The specific gravity of these range between 2–2.8 and bulk density 1120–1300 kg/m^3 (Duggal, 2008).

b. Based on Density

i. Heavy Weight Aggregate: These are aggregates with specific gravity of 4.0 and above, these include scrap iron, ball bearings, ilemenite magnetic and barites. They are mainly used in concretes which require high density such as in radiation shielding in nuclear power plants. The density of heavy weight concrete is more than 3600kg/m^3. Steel shots can produce concrete of about 7000Kg/m^3 density. Garba (2014) also observed that aggregate with specific gravity of 4.0 and above can be used for concrete production for radiation shielding and for concrete weight. These aggregate include scrap iron, ilemenite, ball bearing, magnetic and barites.

ii. Light-Weight Aggregate: They are used to produce low density concretes which are advantageous in reducing 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. These aggregates have specific gravity usually less than 2.6 and an oven-dry density range between 500 to 2000kg/m^3 (BS 812-101, 1990) these aggregate have high porosity, which result in low apparent specific gravity.

Most artificial aggregates fall under this category, e.g. sintered PFA, Foamed slag etc. An example of natural lightweight aggregate is 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. As they all achieve lower specific gravity and increased porosity, they result in lowering in concrete strength. Lightweight aggregates are not as rigid as normal weight aggregates thus produce concretes with higher elastic modulus, creep and shrinkage. The strength properties of lightweight aggregates depend on type, source and whether lightweight fines or natural sand are used. According to (Brook et al, 1991) a density of 1850Kg/m^3 may be considered as the upper limit of a true lightweight aggregate although this value may sometimes be exceeded.

iii. **Normal - Weight Aggregate:** Many natural aggregates are from granites, gravels, basalts, and limestone's etc. fall under this category. All these aggregates have specific gravities within the range of 2.55 to 2.75 and therefore they produce concretes with similar densities, normally in the range of 22.5 – 24.5 kN/m^3 depending on the mix proportions. These are used for making normal structural concrete. Normal weight aggregate should meet the requirement of BS 812 – 2 (1995).

c. Based on Particle Size

a. Classification of Aggregates

Concrete is made with aggregate particles covering a range of sizes up to a maximum size which almost lies between 10mm and 50mm; 20mm which is typical. The particle size distribution is called grading. Low-grade concrete may be made with aggregate from deposits containing a whole range of sizes, from the larges to the smallest, known as all-in or pit-run aggregate. The alternative, very much more common, and always used in the manufacture of

good quality concrete, is to obtain the aggregate in at least two separate lots, the main division being at the size of 5mm or Number 4 ASTM sieve. This divides fine aggregate sand, from coarse aggregate.

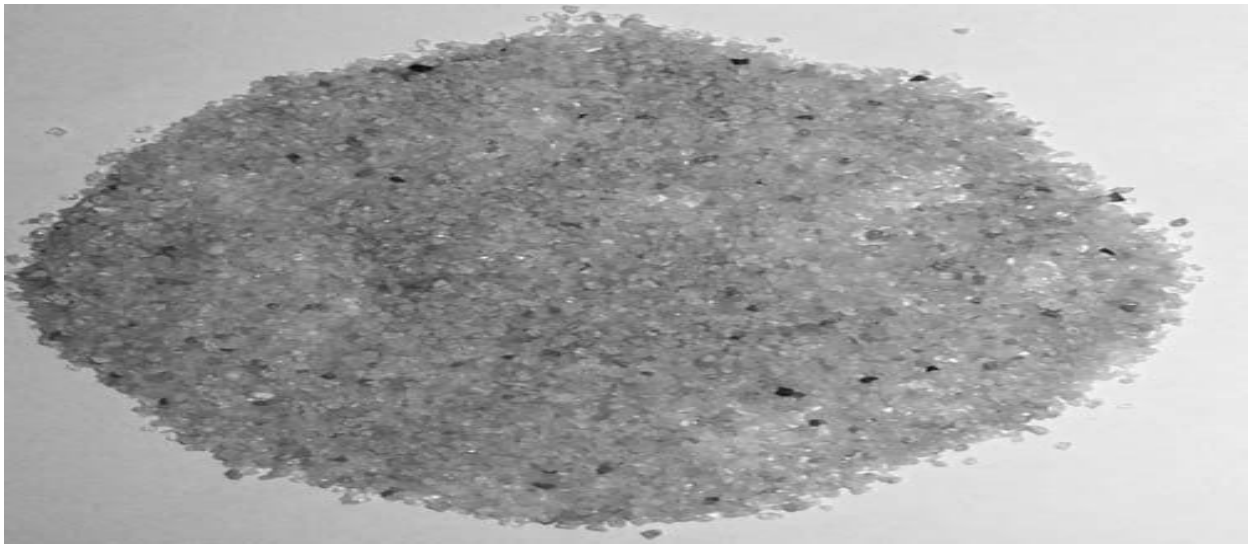
1. Coarse Aggregate: Aggregates predominately retained on a No. 4 (4.75-mm) sieve are classified as coarse aggregate. Generally the size of coarse aggregate range from 5 to 150mm. For normal concrete used for structural members such as beams and columns, the maximum size of coarse aggregate is about 25 mm. For mass concrete used for dams or deep foundations, the maximum size can be as large as 150 mm (Zongjin, 2011).

5~10 mm 10~14 mm 14~20 mm 20~ mm

Source: (Zongjin, 2011) Advance concrete technology.

Plate II: Different sizes of coarse aggregates

2. Fine Aggregate (Sand): Aggregates passing through a No. 4 (4.75 mm) sieve and predominately retained on a No. 200 (75 μm) sieve are classified as fine aggregate. River sand is the most commonly used fine aggregate. In addition, crushed rock fines can be used as fine aggregate. However, the finish of concrete with crushed rock fines is not as good as that with river sand (Zongjin, 2011).



Source: (Zongjin, 2011) Advance concrete technology.

Plate III: Profile of sand

c. Based on Shape and Texture

The external characteristics of the aggregate are important in particular the shape and surface texture with regard to the properties of fresh and hardened concrete.

i. **Shape and Texture of Aggregates:** According to Zongjin (2011) aggregate shape affects the workability of concrete due to the differences in surface area caused by different shapes. Sufficient paste is required to coat the aggregate to provide lubrication. The typical shapes of aggregates are among these, spherical, cubical, and irregular shapes are good for application in concrete because they can benefit the strength. Flat, needle-shaped, and prismatic aggregates are weak in load-carrying ability and easily broken. While the surface texture of aggregates can be classified as glassy, smooth, granular, rough, crystalline, and honeycombed. The surface texture of aggregates has significant influence on the fluidity of fresh concrete and the bond between aggregates and cement paste of hardened concrete (Neville and Brook, 2011).

d. Based on Unit Weight

According to (Duggal, 2008) aggregates are classified as normal-weight, heavy-weight and light-weight aggregate depending on density and specific gravity. The specific gravity and density of normal weight aggregate 2.5-2.7 and 1520-1680, heavy weight 2.8-2.9 and >2080 while light weight aggregate 2.28-2.5 and density <1120.

2.2 Ceramic

The term ceramics is a general term used to refer to ceramic products. Manufactured ceramics include wall tiles, floor tiles, sanitary ware, household ceramics and technical ceramics.

According to Duggal (2008) ceramics are usually brittle, hard and are in the form of amorphous (non-crystalline) or glassy solids. The bond in these materials is mixed ionic and covalent and while these can be made in single crystal forms, their more common structure is glassy. Because of covalent ionic bond the electrons are not free which makes the ceramics, thermal and electrical insulators. At low temperatures, ceramics behave elastically. However, under proper conditions of stress and temperature these deform by viscous flow.

2.2.1 Properties of Ceramic

Mechanical properties of ceramic theoretically tensile strength of ceramics is very high but in practice it is quite low. Tensile failures of ceramics are attributed to the stress concentrations at the pores and micro-cracks at grain corners. The modulus of elasticity ranges from 7 × 104 to 42 × 104 N/mm^2. Glass fibers tensile strength of the order of 700 N/mm^2. The compressive strength is high and it is usual to use ceramics like clay, cement and glass products in compression. Ceramics have very high shear strength with resistance to failing in a brittle

manner. The transverse strength is difficult to ascertain and ceramics are not used in the places where such strength is the criteria (Duggal 2008).

The electrical properties of ceramic materials have no free electrons so they have low electrical conductivity. However, at high temperatures the ionic diffusion is accelerated while the thermal properties of most ceramics have high melting points and as result at high temperatures, these materials resist deformation and retain strength under pressure. Silicon carbide and silicon nitride, for example, withstand temperature changes better than most metals do. Duggal (2008) state that thermal capacity, conductivity and resistance to shocks need to be considered while using a ceramic.

2.2.2 Classification of Ceramic

Ceramic waste can be divided in to two different categories which may vary in accordance with the sources of the raw materials. According to Torgal and Jalali (2010) the first one are all fired wastes generated by the structural ceramic factories that use only red pastes to manufacture their products, such as brick, blocks and roof tiles. The second one is all fired waste produced in stoneware ceramic such as wall, floor tiles and sanitary ware. These producers use red and white pastes; nevertheless, the usage of white paste is more frequent and much higher in volume. In each category the fired ceramic waste was classified according to the production process. This classification is as indicated in Figure 2.

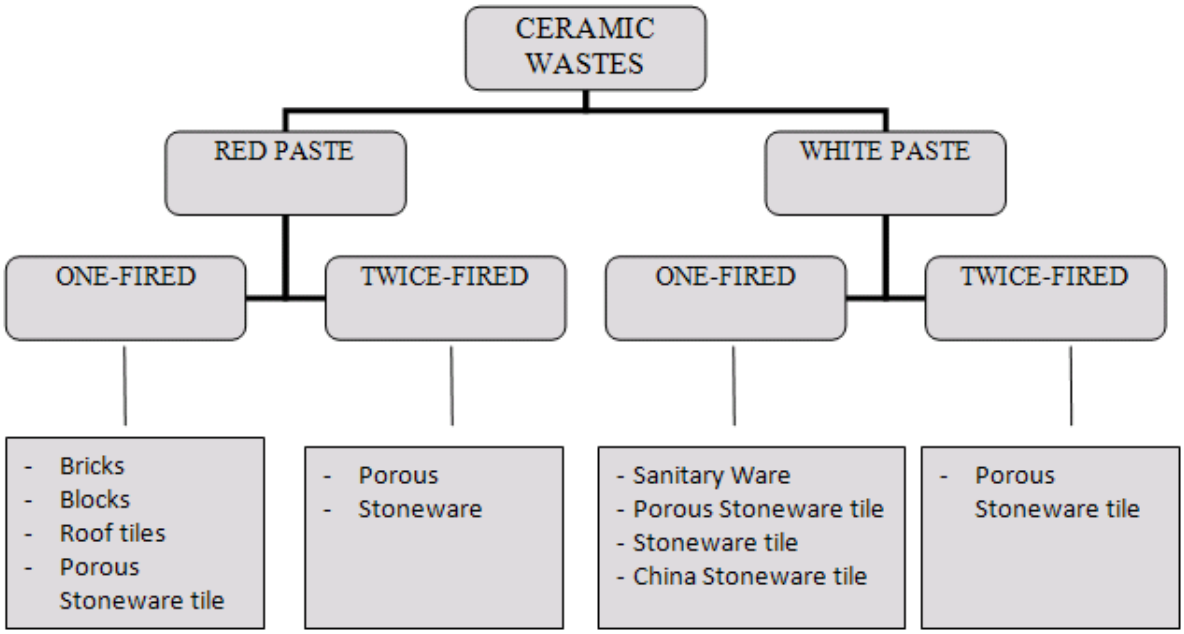


Figure 2.0. Classification of ceramic wastes by type and production process.

Source: (Torgal and Jalali, 2010).

2.2.3 Chemical Composition of Ceramic Paste

According to Pacheco and Jalali (2010) state that alumina and silica are the most important oxides which are present in the ceramic paste. The different between alumina and silica is the type of clay used such as red paste twice fired ceramic, white paste once-fired ceramic, white paste twice-fired ceramic, red paste for stoneware tile, white paste for stoneware tile and white paste for sanitary ware.

2.3 Ceramic Tile

According to www.ceramic.com (2005) defines the ware as a thin flat slab of glazed or unglazed fired clay used on floor for decoration, walls and roofs, sometimes used as extension, thin slab of glass, plastic, stone, asphalt or acoustically sound absorbent materials such as asbestos, as well as hollow ceramic blocks used structurally as partitions. Tiles are mostly defined in terms of their physical, or their constructional purposes, as building

accessories and components and also for their decorative and functional purposes. Therefore the thickness of a tile should be 25% or less the total area in question.

Ceramic tile product is a mixture of minerals and clays to achieve the shaped, pressed, then resulting in a hard surface by fired at temperatures exceeding 2000 degree (F). The ceramic tile added color, finish and make it resistance to odors, bacteria, stains and scratches is the application of protective glaze before firing the ceramic tile.

Source: (www.ceramic.com 2005).

Plate IV: Ceramic tiles sample

2.3.1 Type and Usage of Tiles

Tile can be describes as interior or exterior tile.

The interior tiles are used in-doors e.g. bathroom, kitchen, ceiling, interior floor and wall tiles, etc. exterior tile these are used for out-doors e.g. pavement, roofing, exterior floor and wall tiles, etc. Every tile belongs to two of the mentioned groups.

According to designboom.com (2005) tile are classified into the following types

1. Terracotta Tile: Terracotta tiles have a rustic charm that derives from being made of natural clays, and which is accentuated by variations in tones, textures, and size.

2. Ceramic Mosaic Tile: Unlike pictorial mosaics that are composed of thousands of tiny irregular tesserae, ceramic mosaics use small regular tiles to make geometric patterns of varying complexity.

3. Quarry Tile: Quarry tile refers to tile produced by extrusion method; clay or shale dough is forced through a die in a continuous ribbon, then cut into tiles and fired.

4. Pavement Tile: Pavement-tiles are often confused with quarry tiles because they are similar in size and weight and both are used primarily in flooring applications. Produced by the pressed-dust method, pavement tiles differ from quarry tiles because of the larger range of colors and finish available. Pavement-tiles can come glazed or unglazed, and have very low water absorption usually in the vitreous range.

5. Glossy Smooth Tile: In contrast to textured tiles, smooth glossy tile create a better finish and a more formal look. Also, smooth glossy tiles resist dirt and stains and are easy to clean. As a result, smooth glossy tiles work well in high-maintenance areas that require frequent cleaning, such as kitchens, bathrooms, and entry halls. But they are slippery, and should not be used for floors.

2.3.2 Characteristics of Tiles

Tiles are characterize based on texture, color, stain resistance, dirt resistance, hygiene and effect of temperature on tiles etc. The textures of tile are in two basic tactile and visual, the color performance in ceramic tile are unaffected and will not change or fade from exposure and also resistance to substances that cause spots.

2.3.3 Classification of Tiles

According to geoffering-ceramic.com/china-ceramic-tiles (2005) classification. They classified tile according to its traffic density. Most countries have their own classification. Geoffering-ceramic.com quotes the Chinese classification of floor tiles under the following class.

Class O - Decorative use only, not use on floors

Class I - Light Traffic, for residential bathroom floors, no direct outside access

Class II-Medium Light Traffic: Only for residential interiors with the exception of used in kitchens, stairs, landings and areas near external entries.

Class III - Medium / Heavy Traffic: Apply to all Commercial applications, residential applications which are similar in traffic to residential applications. Specific exceptions are areas of prevalent circulation points

Class IV - Heavy Traffic. Used in all residential and commercial applications such as public areas of exhibition halls, restaurants, supermarkets, shops, hotels and schools.

Class V - Extra heavy traffic. Apply to all residential and commercial applications similar to extra durability.

Class IV -Extra durability perhaps required, suitable for commercial usage and industrial applications.

2.4 Use of Ceramic Wastes as Aggregate

When ceramic waste tiles was crushed and used as aggregates either as partially or fully replacement of granite or crushed stone in concrete. The crushed tiles may have higher compressive, tensile and flexural strength with lower density and higher water absorption. According to Khaloo (1995) investigate the use of crushed tile as a source of coarse aggregate in concrete. The crushed tile had a lower density and a much higher water absorption value compared to natural crushed stones. The result of the concrete made with 100% crushed tile as the coarse aggregate had a lower density and higher compressive (+2%), tensile (+70%) and flexural (+29%) strengths. According to Senthamarai and Devadas (2005) they suggested that the compressive, splitting tensile and flexural strengths of ceramic waste coarse aggregate are lower by 3.8, 18.2 and 6% respectively when compared to conventional concrete. Brito et al (2005) and Correia et al (2006) reported ceramic tile aggregates can be used in elements in which the primary requirement is not compressive strength. However, it

can be used in members wherein tensile strength and abrasion resistance are of primary importance, such as for concrete pavement slabs.

Cachim (2009) used crushed waste from different kinds of ceramic blocks as a partial substitute (15, 20 and 30%) for coarse natural aggregates, observing that with 15% substitution there was no change in concrete strength, whilst when 15-20% was substituted, alterations were noted according to the kind of ceramic block used and when 20-30% was substituted, the recycled concrete showed a reduction in strength regardless of the kind of ceramic block from which the recycled aggregate had been obtained. Binici (2007) used crushed ceramic waste and pumice stone as a partial substitute for fine aggregates in the production of mortar and concrete, finding that the resultant product showed good compressive strength and abrasion resistance, together with less penetration by chlorides which could provide greater protection for the reinforcement used in reinforced concrete. Likewise, Koyuncu et al (2004) analyzed 3 types of ceramic waste (paste, dust and crushed floor tiles) as road sub-base filler and as a substitute for natural aggregates in concrete, demonstrating the feasibility of reuse in non-structural concrete (concrete blocks) with a strength of 40-50 kg/cm^2. Silva et al (2010) analyzed the feasibility of using red ceramic waste as a partial and total substitute for natural fine aggregates, finding that at substitution percentages of 20 and 50% results which were at all times superior to those for the natural fine aggregate mortar. However, when natural fine aggregate was totally substituted, behavior was poorer than that of the red ceramic waste.

Higashiyama et al, (2012) conduct research on the compressive strength and chloride penetration of mortars using ceramic waste as fine aggregates. They used ceramic wastes of electrical insulators. They discovered that mortars with ceramic wastes as fine aggregates gained higher compressive strength than the control mortar made from river sharp sand. They

also made partial substitution of Portland cement with ceramic waste powder smaller than 0.075mm; compressive strength for substitution up to 20% was good enough. Sekaret al (2011) found out through experimentation that the compressive strength of concrete cubes made with ceramic insulator and glass insulator were found to be 16% and 26.34% lesser respectively than that of conventional concrete. Veera (2010) said that replacement of coarse aggregate with ceramic scrap in excess of 20%, leads to reduction of strength below conventional mix. Turgutet et al. (2009) suggested that the replacement of fine aggregate by fine glass at level of 20% by weight had a significant effect on the compression, tension and flexure properties of concrete paving block samples as compared with the control sample.

Medina and Yahlizade (2009) conducted research on the use of wastes from sanitary ware as partial substitute for coarse aggregates in concrete (15 to 25%), and produced positive results. The increase in partial substitution resulted in lower density in concrete, and higher compressive and tensile strength. The concrete produced was suitable for structural use. Lopez et al (2007) conducted investigation on the possibility of utilizing sanitary ware wastes as partial substitution for both coarse and fine aggregates. The study comprised of investigating physical properties of concretes in which conventional coarse aggregate had been partially substituted by coarse ceramic aggregate obtained by crushing ceramic sanitary ware, and natural fine aggregate had been substituted by powdered ceramic material. Satisfactory results were obtained in both cases.

2.5 Recycle Aggregates

Recycled aggregates can be defined as the result of management and waste treatment where, following a process of crushing to reduce size, sieving and laboratory analysis, the waste complies with technical specifications for use in the construction sector and civil engineering.

According to Ignacio (2007) it is not possible to carry out an exhaustive characterization of all kinds of recycled aggregates.

A well burnt clay bricks can be used as coarse aggregates in concrete production to assess the impact on the strength, durability of the concrete and also determine the physical and mechanical properties of the concrete made with burnt clay aggregate. Akhtaruzzaman and Hasnat (1988) used manually crushed, well burnt clay bricks as coarse aggregates and tested four grades of concrete made with crushed brick as aggregate to determine their physical and mechanical properties. The normal compressive strength ranged from 13.8 to 34.5 N/mm^2. For the same grade of concrete, the modulus of elasticity of the concrete produced with crushed brick aggregates was about 30% lower, the tensile strength was about 11% higher and the unit weight was about 17% less than that of natural aggregate normal concrete. He also derived empirical equations predicting the modulus of elasticity and the tensile strength of brick aggregate concrete. However, the modulus of elasticity was 30% less than that of normal concrete.

Kibriya and Speare (1996) also used three different types of brick aggregates to assess their impacts on the strengths and the long-term durability of concrete. The brick concrete had comparable compressive, tensile and flexural strengths to those of normal concrete but the modulus of elasticity was drastically reduced. Mansur et al. (1999) studied the suitability of crushed clay bricks as coarse aggregate for concrete, comparing its basic properties with those of conventional concrete, produced with granite aggregates. Four basic mixes were used corresponding to grades ranging from 30 to 60 N/mm^2. For identical mix proportions, the use of crushed brick aggregates resulted in higher compressive and tensile strengths, lower drying shrinkage, and an almost identical specific creep. However, and in parallel with the previously described study, the use of crushed brick led to a significant reduction in the

modulus of elasticity and a substantial loss in the workability of the fresh concrete. A stress-strain curve equation for brick-aggregate concrete was proposed. Padmini et al (2001) used a fractional factorial experimental design method, studied the relative influence of different parameters on the strength of concrete using low-strength (6-13 N/mm^2) bricks as aggregates. It was found that the strength of brick concrete was most influenced by the cement content, the aggregate conditions (that is pre-wet or dry before mixing) and the strength of brick from which the aggregates were derived.

Another research by Gomes and Brito (2009) use crushed brick aggregates, obtained from brick with higher initial strength, and may exceed the compressive strengths reached using granite aggregate, even allowing for the production of high strength concrete. It is possible to estimate the strength of the concrete with the brick as the coarse aggregate from the strength of the original brick (Gomes and Brito, 2009). This estimation of the compressive strength could be important when recycled bricks from a construction waste are used as an aggregate for a new concrete. On this way it would be possible to determine whether or not that brick type, in a particular condition, is suitable for use as the aggregate for a new concrete with demanded strength.

Devenny and Khalaf (1999) also studied the possibility of using crushed brick as coarse aggregate in concrete, comparing the compressive strength of normal concrete manufactured with granite aggregates with that of concrete made with crushed brick aggregates, obtained from four types of bricks, with compressive strengths varying from 39 to 81 N/mm^2. They concluded that the use of crushed brick aggregates may exceed the compressive strengths reached using granite aggregate, even allowing for the production of high strength concrete, with a simultaneous lower density, which is suitable for low dead-weight applications. The authors observed that concrete compressive strength consistently increases with the brick

compressive strength and with the concrete density. Khatib (2005) used fine recycled aggregates obtained from crushed bricks to replace increasing fractions of the sand of a conventional concrete. For a 50% replacement fraction, no compressive strength reduction was observed and for an integral replacement, the reduction in strength was only 10%.

According to Guerra et al. (2009) it was found that the water absorption of recycled crushed brick aggregate concrete is significantly greater than the one of the natural aggregate concrete. Water is necessary for the corrosion of embedded steel, as it can carry chlorides and sulphates as well as other harmful ions. The presence of water can also cause freeze thaw damage to concrete. The main problem of using the recycled brick as an aggregate for concrete is high water absorption.

2.6 Concrete

Concrete is a composite material and is mainly composed of aggregate, cement and water which are mixed in a particular proportion to get an actual strength. According to Zongjin (2011) when these ingredients are mixed together, they form a fluid mass that are easily molded into shape. Over time, the cement forms a hard matrix which binds the rest of the ingredients together into a durable stone-like material with many uses.

2.6.1 Classification of Concrete

According to Garba (2014) concrete is heterogeneous in all aspect because is mixture of different materials, the heterogeneity of the concrete enables the concrete to be classified into classes.

a. Based on Bulk Density

Normal-weight concrete has a density of about 1800 to 2400kg/m^3 (4000 Ib. /yd^3) they are used for structural purposes made with normal weight aggregate (granite). The lightweight

concrete with less than 650 to 1800kg/m^3 (1080 to 3000 Ib. /yd^3) of oven dry density they are made by the used of lightweight aggregate or addition of foam or air. Lightweight concrete are used in multi-storey where high strength is needed, while the heavyweight concretes with density greater than 3200kg/m^3 (5300 Ib. /yd^3) they are used in radiation shielding and as counter weight made with heavy weight aggregate.

b. Base on Strength

High-strength concrete has a compressive strengths greater than 60N/mm^2 (9000psi) at 28 days or 56 days. Other higher classes of high strength concrete are the ultrahigh strength and high performance concrete which for normal strength concrete at 28 days is between 20-60N/mm^2 (3000 – 9000psi) and for low-strength concrete with 28 days the compressive strength is less than 20N/mm^2 (3000psi) they are used in high loadings e.g. strip footing, floor slabs etc.

c. Base on Sizes of Aggregate

Concrete are classified into; fine grain concrete with aggregate not exceeding 10mm, coarse grain concrete, and no-fine concrete that has no aggregate size less than 5mm.

2.6.2 Properties of Concrete

a. Fresh Concrete

According to Shetty (2009) fresh concrete is a mixed material which can be molded into different shape. The quantities of cement, aggregate, water mixed together and control the properties of concrete in the wet state as well as in the hardened stage.

i. Workability

Garba, (2004) defined workability as the ease with which a given set of materials can be mixed to form a concrete and handled, transported and placed within minimum loss of homogeneity. The term workability mean compatibility, stability and mobility.

Factors affecting workability

- **a.** Mix proportions
- **b.** Water content
- **c.** Shape of aggregates
- **d.** Size of aggregates
- **e.** Surface texture of aggregate
- **f.** Use of admixtures
- **g.** Grading of aggregates

Assessment of workability

According to Garba (2004) workability cannot be measured, it can only be assessed indirectly by measuring compacting factor or slump test.

1. Slump Test: the slump test assists in assessing the consistency of a mix with careful observation of the concrete by assessing the workability of a mix. Slump test is done by filling the slump cone with concrete in three layers by tamping each layer 25 times with a standard rammer of 25mm diameter. After the mould is filled up the top of the cone is then leveled and the cone gently lifted up allowing the unsupported concrete to settle or collapse. The difference between the initial and the final height represent the slump. A workable mix will tend to stick together and subsides unbroken when the mould is removed, while harsh mix breaks. Using the test a mix could have:

a) True slump represent mix with low and medium workability

b) Collapse slump represent mix with high workability

c) Shear slump represent harsh mix, low cement content, grading, poor aggregate, textures and improper shapes, etc.

2. Compacting Factor Test: where concrete of low workability is to be tested, the compacting factor test is more appropriate. Compacting factor can be used even the slump test gives zero as the measurement of the slump. Compacting factor test measure the degree of compaction achieved by standard amount of work done.

The apparatus consist of two conical hoppers A and B fitted with strong doors at their base and a cylindrical container C. The top hopper is filled with concrete using scoop and not to be compact in the hopper. The door at the base of the top hopper is then opened allowing the concrete to fall into the second hopper (B). The door at the base of the second hopper (B) is then opened, allowing the concrete to fall into the cylindrical container (C). The cylinder is then struck off to level the top of the cylinder, no compacting is allowed, the cylinder with its content is weighed.

Cylinder with its content is once weighed. The first weight is the weight of partially compacted concrete; the second weight is the weight of fully compacted concrete. The compacting factor is computed using the relationship below.

Compaction Factor =PC/FC X 100

The compacting factor is expressed to two decimal places. The value of compacting factor ranges from 0.75 to 1.0. Concrete with compacting factor cannot be compacted with hand. Table shows the comparison between slump and compacting factor test.

Table 2.1 Comparison between Slump and Compacting Factor Test

Slump	Compacting factor	Degree of workability
0-25	0.78	Very low
25-50	0.85	Low
50-100	0.92	Medium
100-175	0.95	High

Source: (Garba, 2014)

b. Properties of Hardened Concrete

Concrete is associated with high strength, durability, imperviousness, hardness and mould ability, concrete has thermal capacity but poor thermal insulator. Concrete hardens through chemical reaction between cement and water without air, concrete cures under water when the initial setting has taken place (Neville, 1995).

1. Compressive Strength

Ultimate crushing strength is one of the most important properties of concrete and it is directly related other properties of the concrete. Elvery (1963) stated that concrete of high compressive strength is expected to have good durability when it is subjected to weathering and chemical attack. Concrete has lower strength under tension than compression. A compressive strength of any structural concrete is not expected to be less than $20N/mm^2$.This could satisfy the requirement of BS EN 12390-3 (2000).

2. Tensile Strength

Tensile strength is responsible of reducing formation of cracks in concrete. The compressive strength depends on the compressive strength of coarse aggregate. The splitting test is rather simple to perform, does not require other equipment than that needed for the compression test, and gives an approximately similar value of the true tensile strength of concrete (Neville,1971). In the case of side-splitting of the cubes, the tensile strength is determined

from $0.642P/S^2$and in diagonal splitting it is determined from $0.5187P/S^2$, where P is the load at failure and S is the side of the cube. For the purpose of this research, the diagonal splitting test of cubes has been considered (Gambhir, 2006, Shetty, 2009, and Carneiro and Barcollos 1949).

3. Abrasion Resistance

The abrasion resistance of concrete is largely influenced by compressive strength, mix proportions, finishing and curing. Due to concretes subjected to different types of abrasive wear such as sliding or scrapping result to gradual reduction and in hydraulic structure, abrasion by water may leads to concrete erosion.

4. Water Absorption

This is a physical process that water is drawn by concrete into it pores or capillaries. Concrete should be dense to minimize absorption, sound and adequate cured. Rich mix indicates minimal absorption than hardened lean mix.

The test method that is most commonly used to determine the absorption and rate of absorption (sorptivity) of water in unsaturated hydraulic cement concretes is ASTM C1585. This test consists of exposing the bottom surface of a sample to water and measuring the increase in mass resulting from absorption.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Materials and Method

The research was carried out through the following methods and Materials:

3.1.1Materials

The materials used in this study for the production of the concrete are ceramic waste aggregate, granite aggregates, Sharp River sand, cement and water.

a. Fine Aggregate

Sharp River sand were used for control specimen while crushed ceramic used as fine aggregate for the sample concrete.

b. Coarse Aggregate

Granite coarse aggregate was used for production of control specimen while the crushed ceramic was used as coarse aggregate for the sample concrete.

c. Cement

The cement used for the whole work was Dangote Cement, it is assumed to conform to BS 12 (1996). The cement was obtained from local dealers in Zaria.

d. Water

Water fit for drinking (fresh tap water) was used for the whole work.

3.2 Methods

3.2.1 Production of Aggregate

The ceramic waste aggregates were produced in the laboratory by manually crushing the ceramic waste tiles into fine and coarse aggregates. The manual procedure involves the use of hammer and very hard surface.



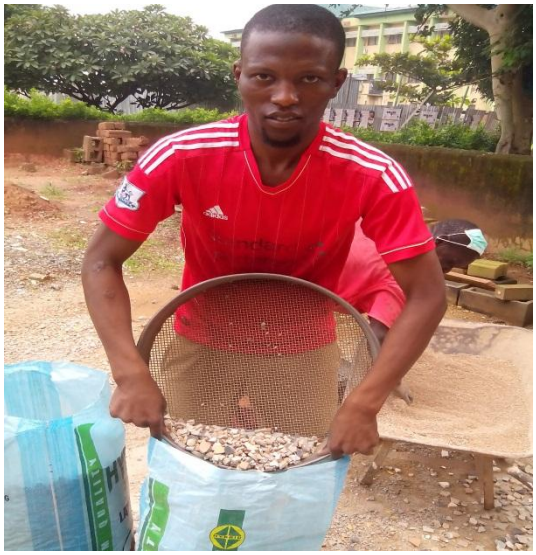



Plate V: Production of ceramic waste tile aggregate

Source: (Experimental work 2015)

3.2.2 Preliminary Tests on Aggregate

Preliminary tests were carried out in accordance with the appropriate standard in order to check the quality for the materials to be used for the experiment. The various tests are:

a. *Particle Size Distribution*

The sieves were arranged from top to bottom to decrease the aperture sizes with pan and lid in order to form a sieving column. The aggregate sample were poured into the sieving column and shaken manually. Sieves were removed starting with the largest aperture sizes, and sieve shaken manually ensuring no material is lost.

The retained material is weighed for the sieve with the largest aperture size and its weight recorded. The same work was carried out for all sieves in the column and their weights recorded. The screened material that remained in the pan stayed weighed and its weight recorded. In accordance to BS 812-103, (1990).

b. Specific Gravity Test

This is the ratio of the weight of the aggregate dried in an oven at 100^0C – 110^0C for 24 hours to the weight of the water occupying a volume equal to that of the solid including the impermeable pores. The latter weight was determined using a vessel (pycnometer) which can be accurately filled with water to a specific volume. The apparent specific gravity of aggregate depends on the specific gravity of the minerals of which the aggregate is composed, the amount of voids, grading, shape, texture and moisture content.

Procedure for Aggregates:

Approximately 2kg of a representative sample of aggregate passing through 20mmretained on 5mm test sieve was taken and the sample was carefully washed with water to remove dust on the surface of the grains. This was follow by soaking in water at 22 ± 3^0C for 24 hours. The specimen was removed from water, shaken off and rolled in large absorbent cloth until all the visible films of water is removed. Large particles may wipe individually. The sample remains weighed and recorded as W_{SD}.

The sample was then placed in a wire basket, immersed in water at room temperature and tapped to remove entrapped air on the surface and between the grains and weighed the sample while immersed. This weight is recorded as W_W.

The sample is later removed from water; dried in a drying oven to a constant weight at a temperature of 105^0C – 110^0C and cooled to room temperature, weighed and recorded as W_{OD}.

Analysis:

Specific gravity on saturated surface-dry basis, $S_{SD} = W_{SD} \div (W_{SD}-W_W)$

c. Bulk Density

The weight of aggregate held in box of unit volume (V) when fill or compacted under defined condition. Aggregate bulk density is usually specified as loose or compacted. The bulk density were determined based on saturated dry surface, the box weighed empty after cleaning as W then filled with aggregate for three different layers and tamped 25 times with tamping rod for compaction. The top of the container was level and weighed again as W_1. The test was carried out for aggregates and the weights were recorded. This could satisfy the requirement of BS 812-108 (1990).

Bulk density (SSD) = $W_1 - W \div V$

d. Water Absorption Capacity

Two portions of aggregate samples were weighed for 1000g. One portion was placed in an oven maintained at 105^0 of 5^0C, and left for 24 hours in the oven. The second portion was put in steel container and pour in water until completely submerged under water, for 24 hours, the sample from oven were removed and weighed, also the soaked aggregate sample was weighed after it has been completely drained. The wetted aggregate was spread on a piece of

paper under a blowing fan until completely surface dried. The water absorption capacity of the aggregates was computed using the relationship below:

$$\text{Water absorption} = \frac{\text{Air weight} - \text{oven dry weight}}{\text{Oven dry weight}} \times 100$$

e. Aggregate Impact Value Test

Materials: 20-10mm aggregate size sample, weighing scale oven, cylindrical steel cup, 15mm standard rammer. In accordance to BS 812-112, (1990).

Procedure:

i. The aggregate samples were dry in an oven at 105^0C for 4 hours and allow cooling.

ii. The cylindrical cup fills with aggregate sample in three layers. Each layer is tamped 25 times with a standard rammer. And the weight of the filled recorded.

iii. A hammer of 13.5-14kg was drop to fall on to the test sample at intervals of not less than 1 second from a height of 380=6mm.

iv. The weight of fraction passing 2.36mm sieve formed as a result of the impacts.

v. The ratios of the weight of fines formed to the total weight of the aggregate sample were express in percentage.

f. Aggregate Crushing Value Test

Procedure:

The aggregate were sieved through 14mm and 10mm sieves and the material retained on 10mm sieve adopted for test. The materials retained were placed in the cylindrical measure and its weight recorded as Wt_1. The aggregate dry in an oven at a temperature of 105^0C for 4 hours and allow cooling.

The test sample placed in three layers in cylinder each layer being subjected to 25 strokes of the tamping rod. The surface of the aggregate was then leveled and the plunger inserted and ensured it rested horizontally on the surface of the aggregates.

The apparatus with the test sample and plunger were then placed in position between the platens of the testing machine and loaded at a uniform rate to the required load. After loading, the crushed material was removed from the cylinder and sieved through 2.36mm sieve. The fraction passing the 2.36mm sieve was then weighed and recorded as Wt_2. In accordance to BS 812-110, (1990).

Aggregate crushing value = $Wt_1 / Wt_2 \times 100\%$

g. Aggregate Surface Texture Test

The aggregate was tested for surface texture by touching and then visualization.

h. Aggregate Shape Test

Aggregates shape was also been tested by visualization and touching.

3.3 Production and Testing of Concrete Specimen

3.3.1 Trial Mix

The main objective of producing trial mixes is to check whether or not the particular aggregates or cement selected for use will behave as anticipated. Adjustments may be made to the original mix proportions, if necessary; the adjustment will differ according to how much the results of the trial mixes differ from the mix proportion.

A mix proportion of 1:2:4 was used and cast 100mm x 100mm x 100mm cubes which were used for the trial and used in order to lower the amount of water required. Four different water-cement ratio was used, that is 0.4, 0.45, 05 and 0.55 after which the optimum (0.55) was chosen.

3.3.2 Final Mix Proportion

The final mix entails the use of nominal mix method of concrete proportioning. A nominal mix proportion of 1:2:4 and a water cement ration of 0.55 were used for the production of concrete specimens. The quantity of material was computed using the absolute volume method. A total of 100 cubes were cast and cured for the ages of 7, 14, 28 and 56days. This was carried out in concrete technology laboratory, Department of Building Ahmadu Bello University Zaria.

3.3.3 Test on Fresh Properties of Concrete

At fresh stage, the concrete samples were tested for workability using compacting factor and slump tests/methods. The test was carried out in accordance with the relevant standard such as BS 1881-102 (1983).

a. Workability Test

1. Slump Test: To determine the slump of fresh concrete mix, the inside surfaces of the mould should be cleaned and oiled to prevent adherence of fresh concrete on the surfaces. The mould were placed on the base plate and firmly held. The cone was then filled with fresh concrete in three layer with each layer compacted with 25 strokes of the tamping rod. After filling the mould, the top surface was struck off by means of rolling action of the tamping rod. Immediately after filling, the cone will be slowly and carefully lifted and after removing the mould the slump of the unsupported concrete was measured and recorded.

Apparatus

i. A standard mold which is a frustum of a cone complying with BS 1881 – 102: (1983)
ii. A standard flat base plate preferably steel.
iii. A standard tamping rod.
iv. Standard graduated steel rule from 0 to 300mm at 5mm intervals.

v. A scoop approximately 100mm wide.

2. Compacting Factor Test: The fresh concrete was placed in the upper hopper up to the top. Then the trap door was opened and allow the concrete falls into the lower hopper. Then the trap door of the lower hopper was then open and the concrete falls into the cylinder. The top of the cylinder was then struck off with trowel and leveled. The cylinder was weighed as W_1 and the value recorded. The cylinder was emptied and refilled with concrete from the same mix in three layers and tamped each layer 25 times in order to obtain full compaction. The top of the concrete in the cylinder was carefully struck off to level with the cylinder. The cylinder was then weighed and the value recorded as W_2.

Compacting Factor = $W_1 \div W_2$

3.3.4 Casting and Curing of Concrete Samples

a. Casting of Cubes

The specimens were cast in iron mould cubes. The moulds were tight with bolts and nuts to avoid leakage; oil was applied on inner surface of the moulds in order to prevent bond between the mould and the concrete. The moulds were filled with concrete in three layers; each being compacted by blows with a tapping rod. The moulds were filled to overflowing and excess concrete removed by sawing action of steel rule. Surface finishing was then done by means of a trowel. The test specimens were then left in the moulds undisturbed for 24 hours and protected against vibration, dehydration and shock.

b. Specimens

Two types of specimens were cast and tested at various ages. All together 100 cube (100mmx100mmx100mm). Control (50cubes), Sample (50cubes) and tested at 7, 14, 28 and 56days of curing age.

c. Curing

After casting the specimens were kept for 24hrs in the laboratory, after which they were de-molded and immersed into water tank and allowed to cure for 7, 14, 28, and 56 days as specify, and crushed, respectively.

3.3.5 Test on Harden Properties of Concrete

At hardened stage, the concrete samples were tested for compressive strength, tensile strength, abrasion resistance and water absorption test at the end of 7, 14, 28, and 56 days curing period.

a. Compressive Strength Test:

After curing the cubes for the specified period, they were removed and wiped to remove surface moisture in readiness for compression test. The cubes were placed with the cast faces in contact with the platens of the testing machine that is the position of the cube when tested should be at right angles to that as cast. The load was applied at a constant rate of stress of approximately equal to 15 N/mm^2 to failure. The readings on the dial gauge were recorded for each cube.

b. Tensile Split Test:

The specimens were weighed placed diagonally at the centering jig with loading pieces carefully positioned along the top and bottom of the plate of the loading system. The load were applied and increased gradually until the concrete cubes fails. The readings observed on the machine were recorded.

The tensile strength was calculated as shown below:

Tensile Strength = $0.5187P \times 1000 / S^2$ (Carneiro, 1949and Shetty, 2009)

Where;

P= Load at failure (N)

S= Surface area of the concrete specimen

c. Abrasion Resistance Test

Each specimen was weighed and the values recorded as W_1 before brushing its surface with a wire brush before applying constant pressure. Wire brushes attached with 3.5kg weight were used to stroke the surface of each specimen up to 60 times at uniform speed. The specimens re-weighed again and the value recorded as W_2. The loss in weight will be calculated by subtracting the final weight from the initial weight ($W_1 – W_2$). The result was expressed as loss in weight to original weight.

d. Water Absorption Test

The water absorption test was carried out in accordance with the BS 1881-122(1983). The specimens from each sample were placed in an oven at 105^0C-110^0C for 24 hours. The specimens were removed from the oven and allow it to cool at room temperature. The specimens were weighed as W_1 and immersed into water for 24 hours, after 24 hours the specimens were removed from the water and dried. The specimens re-weighed as W_2 and the value recorded. The percentage of water absorption should be calculated as.

Water absorption % = $[(W_2 - W_1)/ (W_1)] \times 100$

3.4 Method of Data Analysis

The result of the conducted tests was analyzed using percentage and mean. The arithmetic mean is the central tendency of collection of numbers taken as the sum of numbers divided by the size of the collection. The mean was used to analyze the result of the compressive

strength and tensile strength at different curing period by summing the strength of the cubes for sample concrete and control specimen for a particular day and divided it by the numbers of cubes.

Percentage was also used to analyze the result of abrasion resistance and water absorption by calculating the percentage of water absorption for the entire concrete specimen and the percentage of weight loss.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND DISCUSSIONS

4.1 Presentation of Results of Preliminary Test

The results presented in this chapter are based on the tests carried out to assess the physical and mechanical properties of concrete made with ceramic waste as aggregate. The result includes these of the physical and mechanical properties of the aggregate used, and the mechanical and physical properties of the concrete made with the aggregates.

4.1.1 Physical Properties of Aggregate

The physical properties of ceramic waste tile aggregate and conventional aggregates are presented in Tables 4.1 to 4.3.

a. Particle Size Distribution

Table 4.1 present the results of sieve analysis of fine aggregate (ceramic waste tile) which has been used to determine the fineness modulus as 3.65. According to Garba (2004) fineness modulus of fine aggregates ranges within 2.0 – 3.5 (± 0.2) and the value of ceramic was tile has fallen within the range. The percentage of the fine aggregate passing sieve 600 micron

was 24.5 which fall within the range of 15 – 34, which indicated that the fine aggregate fall within (Zone I).

Table 4.1 Sieve Analysis of Fine Aggregates (Ceramic Tile)

BS Sieve size	Weight retained (kg)	Total weight retained (kg)	Cumulative percentage retained (%)	Weight passing (%)	percentage passing (%)
4.75mm	155	155	7.75	1845	92.3
2.36mm	500	655	32.75	1345	76.3
1.18mm	455	1110	55.50	890	44.5
600µm	400	1510	95.50	490	24.5
300µm	365	1876	93.75	125	6.23
150µm	120	1995	99.75	5	0.25
Pan	5	-	-	0	0
Total			**365**		
Fineness modulus			**3.65**		

Source: (Experimental work (2015)

Table 4.2 shows the result of the sieve analysis of coarse aggregates (ceramic waste tile). The fineness modulus of the aggregates was determined as 5.79. According to Gupta and Gupta (2012) the fineness modulus of coarse aggregates varies from 5.5 to 8.0 and for all in aggregate, between 3.5 and 6.5. This shows that the value of fineness modulus of the aggregate for the research is within the range.

Table 4.2 Sieve Analysis of Coarse Aggregates (Ceramic Tile)

BS Sieve size	Weight retained (kg)	Total weight retained (kg)	Cumulative percentage retained (%)	Weight passing (%)	percentage passing (%)
20mm	26	26	1.73	1474	98.3
10mm	815	841	56.07	659	44
4.75mm	173	1014	67.60	486	32.4
2.36mm	166	1180	78.66	320	21.3
1.18mm	121	1301	86.73	199	13.2
600µm	79	1380	92.00	120	8
300µm	80	1460	97.33	40	3
150µm	30	1490	99.33	10	0.6
Pan	10	-	-	0	0
Total			**579**		
Fineness modulus			**5.79**		

Source: (Experimental work (2015)

b. Specific Gravity, Bulk Density and Absorption Capacity of Aggregate

Table 4.3 shows the specific gravity, bulk density and water absorption capacity of the aggregate. The specific gravity of ceramic tile and granite coarse aggregate were found to be 2.28 and 2.64, while the fine aggregate ceramic tile and conventional fine aggregate were 2.63 and 2.44 respectively. The bulk density of both the ceramic tile fine and coarse aggregate were lighter in weight than that of granite and river sand aggregate which satisfy the requirements of BS 812-108 (1990) that states the range for normal weight aggregates to be between 1280 and 1920 kg/m^3 (for bulk density).

It can be seen that the absorption capacities of both the ceramic tile and granite aggregate in the table shows that the ceramic waste tile absorbed more water about 10% than that of granite aggregate with 4.40%.

Table 4.3: Specific Gravity, Bulk Density and Absorption Capacity of Aggregate

Properties	Ceramic(coarse)	Granite	Ceramic(fine)	Sand
Specific gravity (SSD)	2.28	2.64	2.63	2.44
Bulk density kg/m^3	1274	1539	1449	1600
Absorption capacity (%)	10.0	4.40		

Source: Experimental work (2015)

c. Aggregate Surface Texture and Shape Test

The surface texture of the ceramic waste tile aggregate based on observation and touching has smooth surfaces and rough edges while the shape of the ceramic waste tile aggregate was angular, flaky and elongated in shape.

4.1.2 Mechanical Properties of Aggregates

a. Aggregate crushing value

Aggregate crushing value of the aggregates was done to determine their relative resistance to crushing under a gradually applied compressive load.

Table 4.4 shows the result of crushing value test of ceramic waste tile and granite aggregate. The values of the granite and ceramic waste tile aggregate that passed through sieve 2.36mm was 525 and 375kg. The percentage of the aggregate crushing value for ceramic tile aggregate was found to be 18.11% while the aggregate crushing value for granite aggregate was 21%. Ceramic waste aggregate were found to have higher ability to resist crushing than the granite aggregate. According to Gupta and Gupta (2012) the ratio of the fraction passing should not be more than 45% which shows that the aggregate used has conformed to standard specified.

Table 4.4 Ceramic Tile and Granite Crushing Value

Item		Sample (kg)	Control (kg)
1	Sample Weight	2070	2545
2	Weight passing sieve 2.36mm	375	525
3	Weight retain on sieve 2.36mm	1697	2020
4	Aggregate crushing value (%)	18.11	21
Aggregate Crushing Value		**18.11%**	**21%**

Source: (Experimental work (2015)

b. Aggregate Impact Value

Table 4.5 presents results of ceramic tile and granite aggregate impact value. The test yields a fraction that passes 2.36 mm sieve which was weighed and divided by the fraction retained on a 10mm sieve after sieving through 14mm sieve before test. The weight of aggregate passing 2.36mm sieve was found to be 530kg (granite aggregate) and 435kg (ceramic waste aggregate). The percentage of aggregates impact value for granite and ceramic waste tile aggregate was found to be 15% and 11.22% respectively which indicates that the ceramic waste tile aggregate is more resistant to impact than granite aggregate, this is in line with the 45% specified by Gupta and Gupta (2012).

Table 4.5 Ceramic Tile and Granite Impact Value

Item		Sample (kg)	Control (kg)
1	Sample Weight	490	620
2	Weight passing sieve 2.36mm	55	90
3	Weight retain on sieve 2.36mm	435	530
4	Aggregate crushing value (%)	11.22	15
Aggregate Impact Value		**11.22%**	**15%**

Source: (Experimental work, 2016)

4.1.3 Fresh Concrete

a. Workability

Slump test was used to control workability, which is the amount of useful work required to obtain full compaction. Slump test does not measure workability directly, but it is commonly used in site work to detect variations in the consistency of mix of given proportions. Slump test is a means of assessing the consistency of fresh concrete.

1. Slump Test

Figure 4.1 shows the relationship between slump and the concrete made with ceramics waste tiles and the control concrete. The detail results is shown in table 1 of appendix A that the control concrete has a slump of 7mm while ceramic waste tile concrete has a slump of 4mm.

This gives an indication of the water absorption and slightly elongated nature of the ceramic waste aggregate, which affect workability of the concrete. The porous nature of ceramic waste aggregates results in high water absorption hence if the aggregate is used dry at mixing time, it will rapidly absorb water leading to harsh mixes with very low workability. Aggregates should be brought to saturated surface dry condition before mixing process by the addition of the required amount of water according to BS 1881 – 125 (1983).

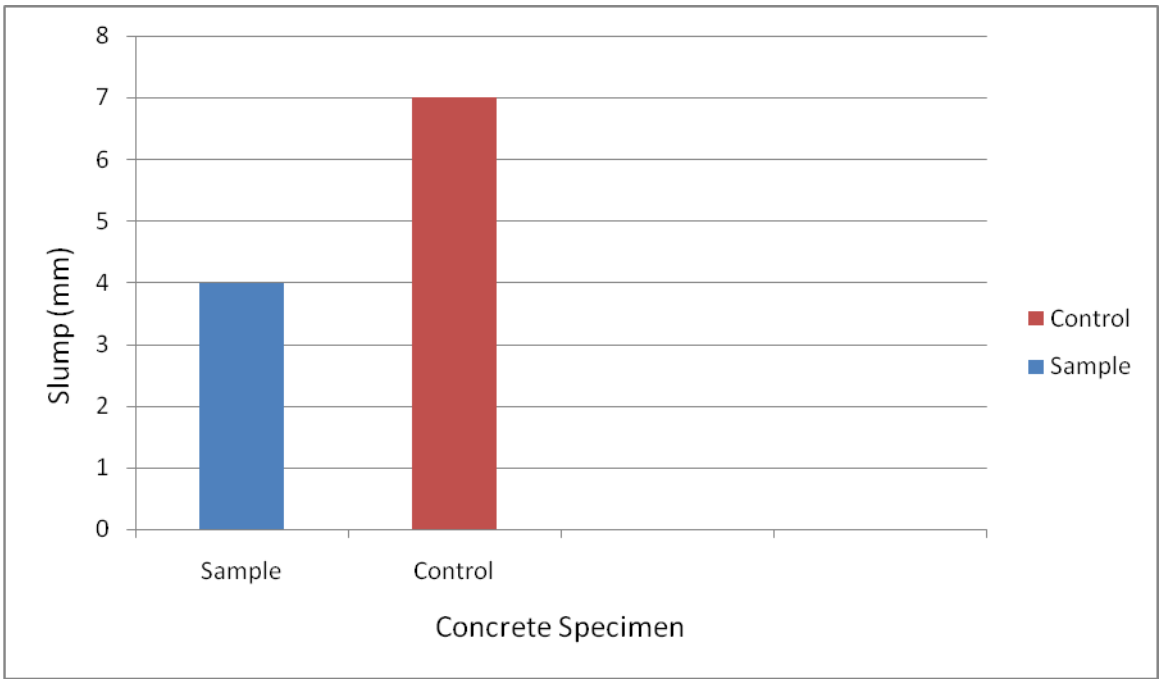


Figure 4.1: Slump of Control Concrete and Sample Concrete

Source: (Experimental work, 2015)

2. Compaction Factor Test

Figure 4.2 presents the compacting factor test of control and ceramic waste tile concrete and the calculations are in Appendix A. It can be seen that the result of the compacting factor test of control and ceramic waste tile concrete was found to be 0.80 and 0.78 respectively. The compacting factor shows that control concrete is more workable than the ceramic waste concrete. It was found that both slump test and compacting factor for both the concretes made with ceramic waste tile and the control concrete shows that, the degree of workability was very low. Therefore this fall within the range specified by Gupta and Gupta, (2012) which varies from 0.78 to 1.0.

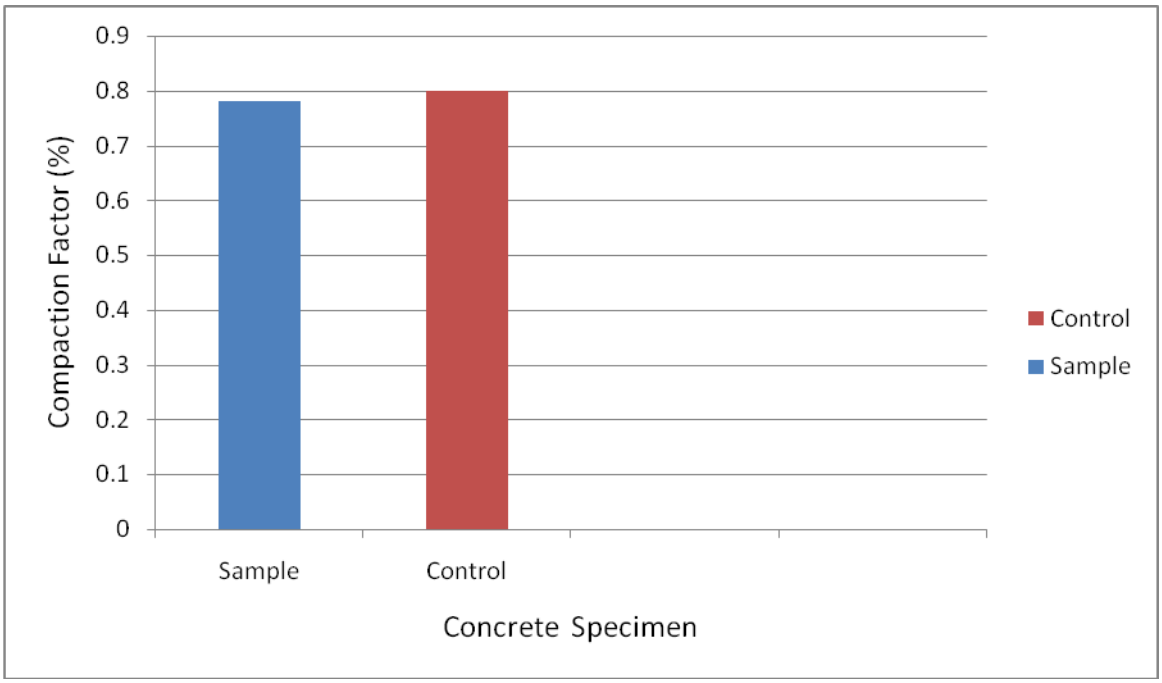


Figure 4.2: Compacting Factor of Control Concrete and Sample Concrete

Source: (Experimental work, 2015)

4.1.4 Hardened Properties of Concrete

a. Compressive Strength

Figure 4.3 shows the compressive strength of concrete specimens cured in water at 7, 14, 28 and 56 days of curing period.

Figure 4.3 presents the relationship between compressive strength and curing age (days). The detail results shows in Table 2 of Appendix B the compressive strength of ceramic waste tile concrete for each of the four curing period is higher than the control concrete. The compressive strength of both ceramic waste tile and control concrete varied from 12.55 to 23.70 N/mm^2. This shows that using 100% replacement of ceramics waste tiles as both fine and coarse aggregate, there was increase in the compressive strength beyond those that obtained from granite aggregate concrete (control specimen). This could be due to the rough and angular edges of the ceramic waste tile aggregate.

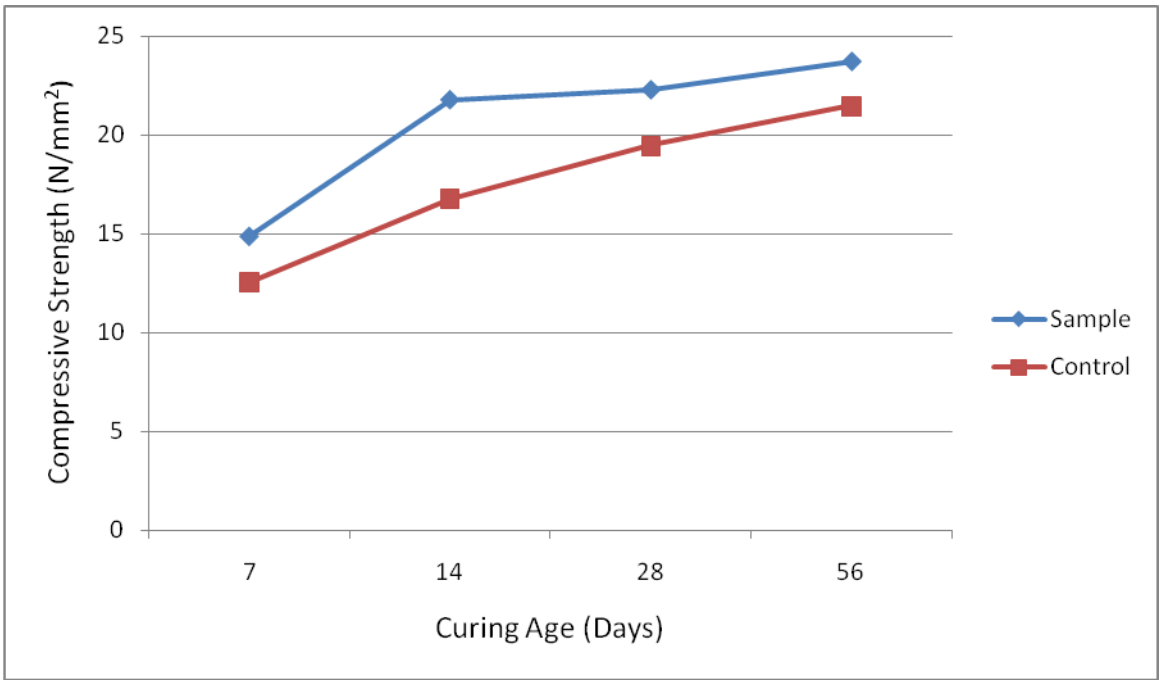


Figure 4.3: Compressive Strength of Control Concrete and Sample Concrete

Source: (Experimental work, 2015)

b. Tensile Strength

The result of the tensile strength of control concrete and ceramic waste tile concrete are shown in Figure 4.4 and detail results are in Table 3 of Appendix B which presents the average tensile strength of the two concrete specimen, it can be observed that at the early period of curing, the average tensile strength of the ceramic waste tile concrete is greater than that of control concrete in all of the curing period (7, 14, 28 and 56 days) respectively. The increase in tensile strength continued steadily throughout the curing period.

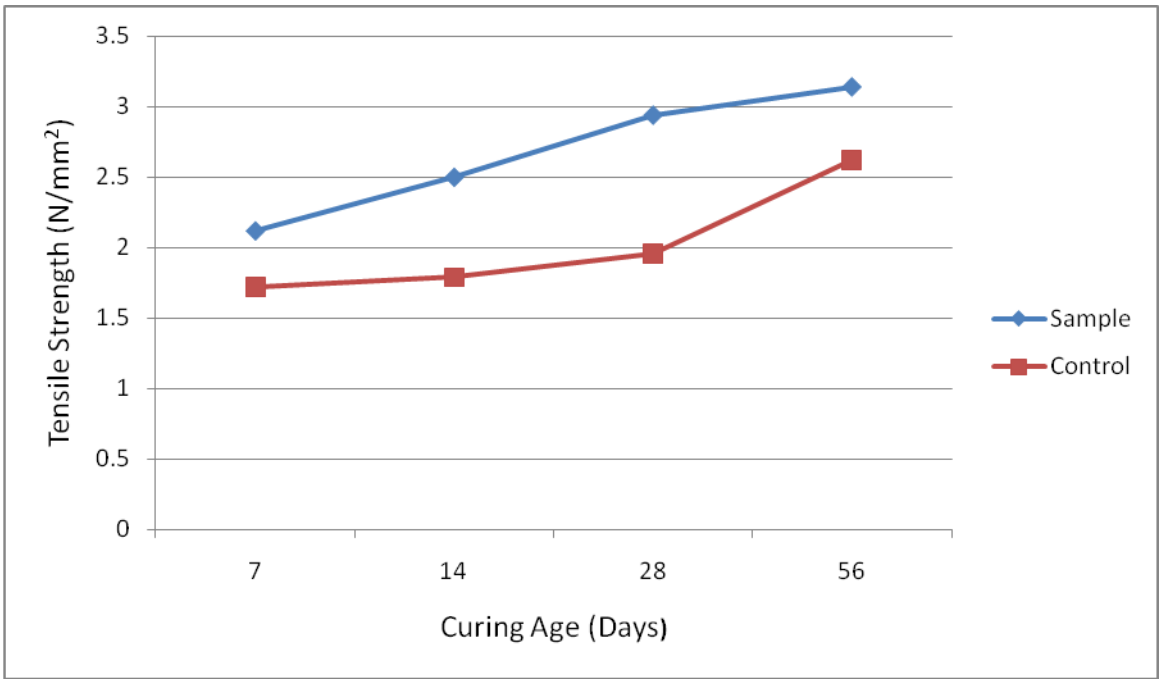


Figure 4.4: Tensile Strength of Sample Concrete and Control Concrete

Source: (Experimental work, 2015)

c. Absorption Capacity

Figure 4.5 express water absorption results of control concrete and ceramic waste tile concrete and details shown in Table 4 of Appendix B. The control concrete has lower water absorption than the sample concrete at 28 days having water absorption of 5.49% and 8.68% respectively. From the result it can be understood that the ceramic waste tile concrete has higher water absorption value compared to control concrete. This is due to the fact that the opposite sites of the ceramic waste tiles has rough surface and therefore porous in nature. Hence the water absorption capacity is higher.

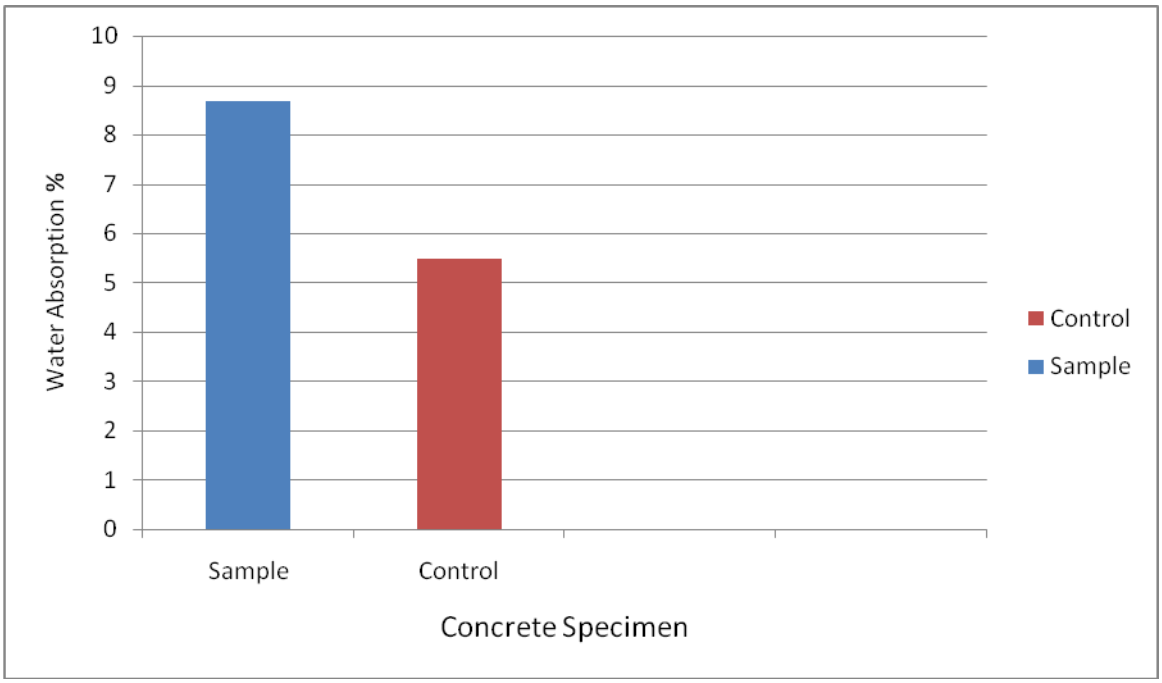


Figure 4.5: Water Absorption of Control Concrete and Sample Concrete

Source: (Experimental work, 2015)

d. Abrasion Resistance

Figure 4.6 shows the abrasion resistance of control concrete and ceramic waste tile concrete at 28 days of curing period. The detail shown in table 5 of appendix B the loss weight of ceramic waste tile concrete is less than that of control concrete specimen. This indicate that the ceramic waste tile concrete is resistant to abrasion compared to control concrete. The percentage loss after abrasion at 28 days, the ceramic waste tile concrete losses a weight of about 0.09% and the control concrete about 0.16%. This may possibly be due to the smooth surfaces of the ceramic waste tile aggregate.

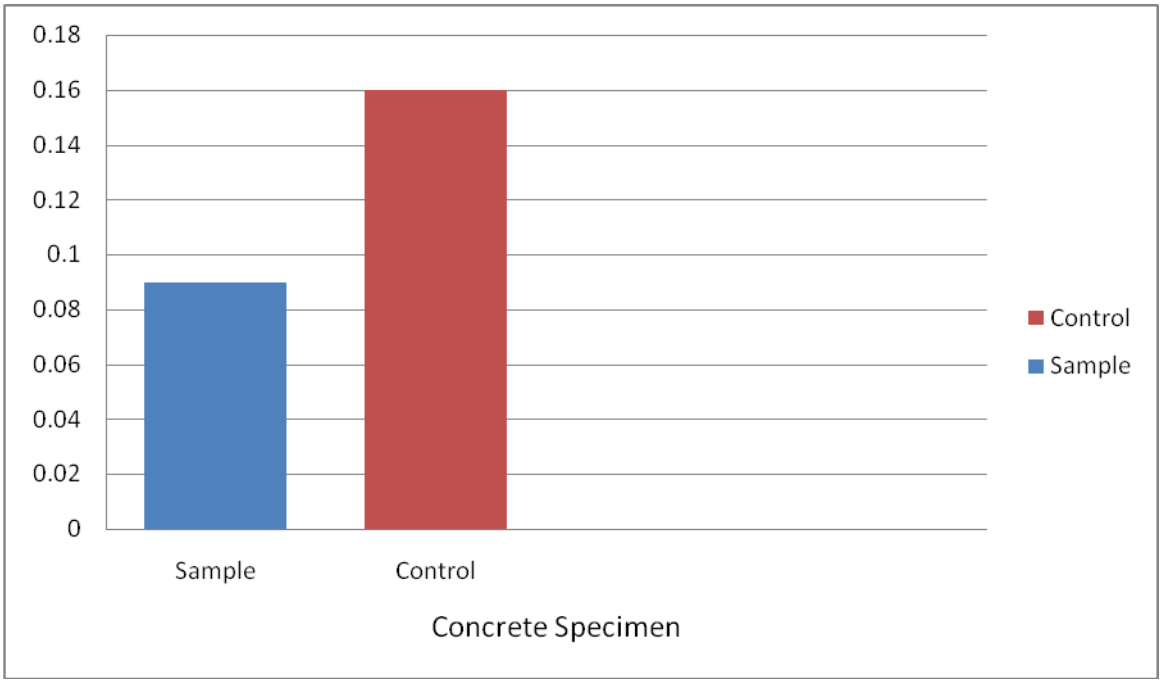


Figure 4.6 Abrasion Resistances of Sample Concrete and Control Concrete

Source: (Experimental work, 2015)

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECCOMMENDATIONS

5.1 Summary of the Research Findings

A study was conducted on the assessment of the properties of concrete made with ceramic waste tile as both fine and coarse aggregates. The concrete sample made with aggregates were tested and compared for workability using slump and compacting factor test, compressive strength, tensile strength, abrasion resistance and water absorption capacity. The highlight of the major findings are.

1. The control concrete has higher slump and compacting factor than the ceramic waste tile concrete by about 55% slump and 2% compacting factor separately.

2. In terms of compressive strength, the ceramic waste tile concrete has higher compressive strength at 7, 14, 28 and 56 days by almost 17%, 26%, 13.46% and 9.82%than the control respectively.

3. The ceramic waste tile concrete has developed higher tensile strength than the control sample at all curing period in that order of about 20.83%, 33%, 40% and 18.05%.

4. The ceramic waste tile concrete is more resistant to crushing and impact value than the control aggregate by about 14% and 28.8%.

5. Control concrete exhibited low water absorption capacity than the ceramic waste tile concrete at 28 days by approximately 45%.

6. The ceramic waste tile concrete showed more resistance to abrasion than the control concrete by about 56%.

5.2 Conclusions

Based on the experimental results obtained from this study, observations and analysis on the assessment of the properties of concrete made with ceramic waste tile aggregate. The following conclusions are drawn.

1. Based on the research carried out the ceramic waste tile as both fine and coarse aggregate were found to have bulk density of 1449 and 1274kg/m^3, and specific gravity of 2.63 and 2.28 respectively. Water absorption capacity of 10%, a crushing value of 18.11% and an impact value of 12.22%. These values are within the ranges of standards.

2. The nominal mix ratio adopted was 1:2:4 with water cement ratio of 0.55. The compressive strength for the ceramic waste tile concrete at 28days of curing age was 22.27kN/mm^2 while that of control concrete was 19.46kN/mm^2. Therefore the nominal mix ratio used was suitable.

3. The mechanical and physical performance, in terms of compressive, tensile strength and slump test indicated that the use of ceramic waste tile as aggregate for concrete is suitable.

4. Based on analysis of the results obtained the ceramic waste tile concrete has a higher strength and durability such as abrasion resistance test compare to that of conventional concrete.

5.3 Recommendations

1. The ceramic waste tile concrete could be used for structural concrete because of it higher strength than the normal concrete. Hence, it is observed that ceramic waste tile can be used as an alternative construction material.

2. It is also recommended that the ceramic waste tile can be transformed into useful crushed coarse aggregate instead of natural coarse aggregate. Since the properties of ceramic waste tile coarse aggregate are well within the value of concrete making aggregates.

3. The study recommended that the ceramic waste tile concrete can be used in building construction. Therefore the ceramic waste tile concrete has higher abrasion resistance than the conventional concrete.

5.4 Recommendations for Further Studies

1. Further research should be carried out to assess the durability of the concrete made with ceramic waste tile concrete in aggressive environment.

2. A comparative study should be carried out on concrete made with ceramic waste tile from different type of ceramic waste industries.

3. Further research could be done on fire resistance, acid resistance and flexural strength of this kind of ceramic waste tile concrete.

5.4 Contributions to Knowledge

1. The research provides experimental confirmation of the promising potential of a new construction material for concrete production.

2. The research has revealed that, the strength of concrete produced with ceramic waste tile as fine and coarse aggregate is stronger than the conventional concrete.

3. It has been confirmed that ceramic waste tile aggregate can be used as both fine and coarse aggregate in concrete production.

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APPENDIX A

Table 1: Slump Test of Control and Sample Concrete

Type of Concrete	Slump (mm)
Control	7
Sample	4

Compacting Factor Test

Control (Concrete)

Empty weight of the container = 6.2kg

Weight of partially compacted concrete = 15.2 – 6.2=9kg

Weight of fully compacted concrete = 17.4 - 6.2=11.2kg

$$\text{Compacting Factor} = \frac{\text{Weight of partially compacted concrete}}{\text{Weight of fully compacted concrete}}$$

$$9/11.2 = 0.80$$

Sample (Concrete)

Empty weight of the container = 6.2kg

Weight of partially compacted concrete = 13.25 – 6.2=7.05kg

Weight of fully compacted concrete = 15.20 - 6.2=9kg

$$\text{Compacting Factor} = \frac{\text{Weight of partially compacted concrete}}{\text{Weight of fully compacted concrete}}$$

7.05/9 = 0.78

APPENDIX B

Table 2: Average Compressive Strength of Ceramic Waste Tile and Granite Concrete

	Compressive strength N/mm^2			
Concrete Type	**7 days**	**14 days**	**28 days**	**56 days**
Control	12.55	16.78	19.46	21.48
Sample	14.88	21.77	22.27	23.70

Table 3: Average Tensile Strength of Ceramic Waste Tile and Granite Concrete

	Tensile strength N/mm^2			
Concrete Type	**7 days**	**14 days**	**28 days**	**56 days**
Control	1.72	1.79	1.96	2.62
Sample	2.12	2.50	2.94	3.14

Table 4: Water Absorption Test of Ceramic Waste Tile and Granite Concretes

	Water absorption (%)

Concrete Type	28 days
Control	5.49
Sample	8.68

Table 5: Abrasion Resistance Test of Ceramic Waste Tile and Granite Concretes

	Loss of weight (%)
Concrete Type	**28 days**
Control	0.16
Sample	0.09