

**EFFECT OF WASTE CERAMIC TILE AS PARTIAL REPLACEMENT OF
COARSE AGGREGATE ON THE COMPRESSIVE STRENGTH AND
DURABILITY OF CONCRETE.**

BY

OMO-AMAYO, Owens Jeffrey

ENG1704128

**A PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING
(B.Eng) DEGREE.**

IN

**THE DEPARTMENT OF STRUCTURAL ENGINEERING,
FACULTY OF ENGINEERING,
UNIVERSITY OF BENIN, BENIN CITY, NIGERIA**

SEPTEMBER, 2023

CERTIFICATION

This is to certify that this work was carried out by Omo-Amayo, Owens Jeffrey, Mat. No. ENG1704128 of the Department of Civil Engineering, Faculty of Engineering, University of Benin City, Edo state, Nigeria.

PROJECT COORDINATOR:

Name: Engr. E. Oria-Osifo

Signature and Date:

SUPERVISOR:

Name: Engr. O. Osasu

Signature and Date:

HEAD OF DEPARTMENT:

Name: Dr. Ngozi I. Ihimekpen

Signature and Date:

DEDICATION

I dedicate this project to the Almighty God, for guiding me to this point in my academic journey.

I would like to extend this dedication to my dear parents and brother, whose unwavering support and understanding have played a crucial role in guiding me along my academic journey. May the blessings of God always be with them, both now and in the future.

ACKNOWLEDGEMENT

I acknowledge the Almighty God, for giving me the strength required to complete this project work.

My gratitude goes to the Head of Civil and Structural Engineering Department, University of Benin; Engr. Dr. N. Ihimekpen, to the project coordinator of Civil and Structural Engineering Department, University of Benin; Engr. E. Oria-Osifo, to my course lecturers, Late Engr. J. Ekhodiaehi, Dr. R.O. Ogirigbo, Prof. O.U. Orie, Engr. Dr. J.O. Okovido, Engr. Dr. S.O. Osuji and all others, as well as the laboratory supervisors of Civil and Structural laboratory, University of Benin, for their guidance and efficient management of the affairs of the department, which has directly and indirectly contributed to the success of this project work.

I am also thankful to my supervisor, Engr. O. Osasu, for his invaluable patience, guidance and assistance throughout the execution of this project.

Finally, I would like to appreciate my family, Mr. B. Omo-Amayo, Mrs. J. Omo-Amayo and Mr. K. Omo-Amayo, for their appreciation, encouragement and keen interest in my academic achievements.

ABSTRACT

This experiment studies the effect of waste ceramic tile aggregate as partial replacement of conventional coarse aggregate on the compressive strength and durability of concrete, in an attempt to determine the possibility of utilizing waste ceramic tile aggregate (WCTA) as partial replacement for conventional granite in concrete production.

For the experiment, a M25 grade concrete with a water/cement ratio of 0.5 was prepared using granite substituted with WCTA at a replacement percentage of 0%, 10%, 20%, 30%, 40% and 50%. Tests such as sieve analysis and aggregate impact value was performed on the various aggregates used in the study to determine their suitability. Concrete cubes of size 100mm×100mm×100mm were casted and tested for compressive strength after a curing period of 7 and 28 days. Water absorption test was also performed on the hardened concrete mixes to determine their durability.

From the experimental results, it is found that the 7th day compressive strength of the concrete mixes are 21.32N/mm², 25.37N/mm², 23.54N/mm², 24.20N/mm², 22.21N/mm² and 20.47N/mm², while 28th day compressive strength is found to be 29.66N/mm², 29.80N/mm², 31.94N/mm², 33.59N/mm², 29.65N/mm² and 27.80N/mm², for 0%, 10%, 20%, 30%, 40% and 50% substitution respectively. Also the water absorption of the concrete samples is observed to be 2.36%, 2.47%, 2.21%, 1.64%, 1.98% and 2.14% for 0%, 10% ,20% ,30%, 40% and 50% respectively. The result reveals that the use of WCTA as partial replacement of coarse aggregate in concrete leads to the enhancement of the compressive strength of concrete, as long it doesn't exceed 30% replacement. Also the addition of WCTA leads to an increase in the water absorption of the concrete for 10% substitution with WCTA, while it leads to a decrease in water absorption for 20-50% substitution with WCTA, with 30% having the least water absorption. Therefore it is recommended to limit the replacement of granite with WCTA to a maximum of 40%, while for optimal strength and durability of structural concrete, replacement of granite with WCTA should be kept at 30%.

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ACRONYMS

AIV - Aggregate Impact Value

DOE - Department Of Environment

WCTAs - Waste Ceramic Tile Aggregates

CTA - Crushed Tile Aggregate

W/C - Water/Cement

G/S - Gravel/Sand

CTW - Ceramic Tile Waste

CWC - Ceramic Waste Concrete

CWA - Ceramic Waste Aggregate

CWAC- Ceramic Waste Aggregate Concrete

WCT - Waste Ceramic Tiles

TAC - Tile Aggregate Concrete

NAC - Natural Aggregate Concrete

CFA - Ceramic Fine Aggregate

CCA - Ceramic Coarse Aggregate

OPC- Ordinary Portland Cement

WCTA - Waste Ceramic Tile Aggregate

CTM - Compressive Testing Machine

C. S - Compressive Strength

W.A - Water Absorption

NAC - Natural aggregate concrete

WCTAC10 - Concrete with 10% substitution of waste ceramic tile aggregate

WCTA20 - Concrete with 20% substitution of waste ceramic tile aggregate

WCTA30 - Concrete with 30% substitution of waste ceramic tile aggregate

WCTA40 - Concrete with 40% substitution of waste ceramic tile aggregate

WCTA50- Concrete with 50% substitution of waste ceramic tile aggregate

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Concrete, a composite substance, is created by mixing binding material, aggregates, water and often additives or admixtures in specific proportions. These ingredients are mixed together to produce a paste which gradually solidifies to create a solid and durable material. Owing to its characteristics, including strength, versatility, durability, cost-effectiveness, and more, concrete is widely used around the world and its application has significantly contributed towards the advancement of modern infrastructure.

Concrete making can however be associated with significant environmental consequences including the exhaustion of earth's finite resources. The aggregates in concrete are of two types, which includes fine aggregate (sand) and coarse aggregate (gravel, crushed stones e.t.c). They are an indispensable component of concrete that contribute to its overall strength performance and volume, with it accounting for sixty to seventy percent of the overall concrete's volume. They are however non renewable natural resources(Subedi et al., 2020), whose extraction and processing process has a significant environmental impact including environmental pollution/emission of greenhouse gases, habitat destruction, and the depletion of natural resources. Also long distance transportation of the aggregates to the concrete production sites can significantly contribute to increased construction cost.

Many research has been performed in order to discover substitute components to supplant traditional aggregates in concrete, for the purpose of mitigating the exhaustion of natural resources, in addition to enhancing the properties of concrete. Among these

investigations, the employment of discarded ceramic tiles as coarse aggregates in making concrete, not only address the search for an improved substitute for the conventional constituent of concrete but also the need for a more sustainable concrete production.

Ceramic tiles are produced by firing natural geomaterials such as clay, feldspars, quartz etc at high temperatures(Elçi, 2015). During the course of manufacturing, transportation, usage and demolition of aging structures, a substantial quantity of ceramic tiles ends up being discarded. In the ceramic industry, it has been estimated that 30% of the daily production goes to waste (Senthamarai and Manoharan, 2005), and most of these waste are often not recycled but discarded. Due to the nature of ceramic waste tiles being highly resistant to physical degradation, it can constitute to environmental pollution if they are improperly disposed.

The ceramic waste tiles are durable and hard, having a significant specific gravity value while being lighter than typical stone aggregates. Furthermore, they exhibit high resistance to biological, chemical and physical degradation(Subedi et al.,(2020). Due to these favourable properties they appear to be possible alternatives for the conventional coarse aggregates in concrete.

Re-using of tile as aggregate in concrete production would considerably minimize the problem of the waste material disposal and simultaneously will also help the preservation of natural aggregate(Elçi, 2015), hence the many research that has been conducted on its use as replacement for the natural aggregate in concrete, some of which are highlighted in the literature review of this research paper.

1.2 STATEMENT OF PROBLEM

Concrete is an essential building material that is used in different sectors such as the construction industry, energy industry, transportation, agriculture, farming etc. It is regarded as the most commonly utilized building material across the globe, and the need for it is steadily growing owing to urban and infrastructure development, population growth, economic growth etc.

However, concrete production is a substantial contributor to the worldwide consumption of natural resources, with natural aggregate (such as gravel, crushed stone and sand) being a major component of concrete. The production of aggregate has become difficult over time due to depletion of suitable sources, cost of extraction and processing, environmental regulations, opposition from local communities, environmental impact and rehabilitation etc. Hence, there is need to explore the use of substitute materials that can be utilized instead of the conventional aggregates of concrete to avert their depletion and to cut down cost associated with quarrying operations.

A huge amount of ceramic tiles often goes to waste. This unused ceramic waste tiles are often repurposed for applications such as pavement or sent to landfills(which may cause environmental pollution if not properly disposed off). But with ceramic tiles having the favourable properties that it has, it can be recycled and may be employed as a replacement for the conventional coarse aggregate in concrete, which can prove to be more economical, environmentally friendly and may provide an improved concrete specimen than that produced using the normal aggregate(gravel) of concrete.

Hence the use of ceramic tile coarse aggregate as replacement for the typical coarse aggregate of concrete is a path worth exploring owing to all its potential benefits.

1.3 AIM AND OBJECTIVES OF THE STUDY

The primary aim of this study is to analyse the physical characteristics of concrete when incorporating crushed ceramic tiles as coarse aggregates, and therefore assess the practicality of utilizing discarded ceramic tile aggregates as substitutes for natural coarse aggregates in concrete mixtures.

The specific objectives of this study are to;

1. To assess how varying proportions of waste ceramic tile aggregate, utilized in lieu of some conventional coarse aggregate, impact the workability and compressive strength of concrete.
2. To determine the ideal percentage of waste ceramic tile aggregate to replace natural coarse aggregate in order to achieve optimal concrete characteristics.
3. To investigate the feasibility of incorporating waste ceramic tile in producing concrete.
4. To explore the water absorption characteristics of concrete incorporating waste ceramic tile as coarse aggregate.

1.4 SCOPE OF WORK

This research is primarily focused on the possible use of crushed ceramic tile waste as partial replacement for granite in the production of concrete. The study was predominantly conducted in a laboratory.

Discarded ceramic tile were sourced from a building site and broken into irregular size of an average size of 20mm using an hammer. While other materials such as granite, sand and cement was obtained from a local shop.

Tests including sieve analysis and aggregate impact value(AIV) test was carried out on the aggregates, after which a mix design for M25 concrete was created based on the Department Of Environment (DOE) method.

Concrete specimens were then fabricated, incorporating the broken ceramic tiles as substitutes for granite at percentages ranging from 0% to 50% by mass. The concrete's workability for each specimen were also evaluated. Following casting, the concrete was left to cure for durations of both 7 and 28 days, after which tests were performed to assess the compressive strength and water absorption of the hardened concrete.

The result gotten for both concrete with and without crushed ceramic tile was then recorded and compared.

1.5 JUSTIFICATION OF STUDY

The study is essential because if found feasible, incorporating waste ceramic material in producing concrete could offer substantial benefits including significantly minimizing waste disposal issues, preservation of natural resources(aggregate) and leading to a more cost effective and environmentally friendly concrete production.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

A significant proportion of concrete relies on non-renewable materials known as aggregates. To meet the increasing need for natural aggregates and address concerns regarding resource depletion, cost increment and environmental degradation, numerous researchers have explored alternative materials, such as industrial and agricultural waste materials such as plastic waste, broken glass, sawdust, ceramic, rice-husk ash, coconut shells, e.t.c, as potential substitutes for traditional aggregates in concrete. Some of these waste materials have demonstrated promising results, with certain cases even improving the structural and durability performance of concrete.

Ceramic tile waste is among the material which has a high potential as aggregate replacement in concrete production(Peter et al.,2020). This chapter delves into the utilization of ceramic tile aggregate as a viable substitute for traditional coarse aggregate in concrete. It encompasses an extensive review of pertinent literature concerning ceramics and the integration of ceramic waste materials as partial substitute for typical aggregate in concrete making.

2.2 CERAMICS

The term ceramics originates from the ancient Greek word “keramiko's”, which signifies "of or for pottery"(Liddell, et al.). It is any of the various hard, brittle, heat resistant and corrosion resistant materials made by shaping and then firing an inorganic, non metallic material such as clay at a high temperature (Heimann and Robert, 2010)(free dictionary).

The earliest human-made ceramics consisted of pottery items such as pots, vessels, or figurines crafted from clay, either in its pure form or in combination with materials like silica. These items are hardened and fused through exposure to intense heat. As time progressed, ceramics evolved to include the practice of glazing and firing to achieve smooth and colored surfaces. This process reduced porosity by applying glassy, amorphous ceramic coatings atop crystalline ceramic substrates.(Carter and Norton, 2007).

Ceramics today encompass a diverse array of products, spanning domestic, industrial, and construction applications, along with an extensive range of materials designed for advanced ceramic engineering purposes. Examples of frequently produced ceramics encompass floor tiles, sanitary ware, wall tiles, household ceramics, and technical ceramics(Awoyera et al., 2016), as depicted in Figure 2.1.

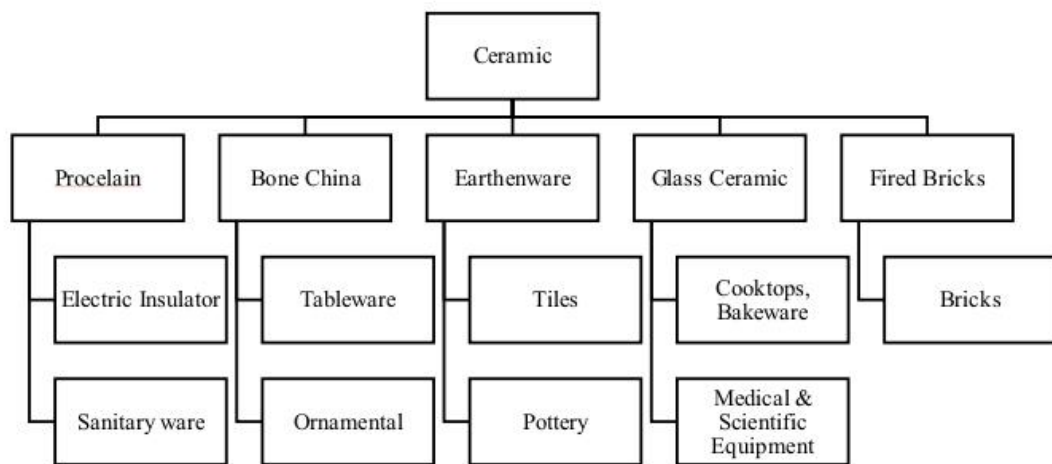


Figure 2.1: Bifurcation ceramics. (Goyal et al., (2022))

2.3 CERAMIC TILE WASTE

Ceramic tiles are decorative, flat, thin pieces made from clay that are used for covering floors, walls or other surfaces. Owing to their brittle nature, a significant amount goes to

waste during construction, transport and utilization. However, there are no harmful chemicals in tile. Waste tile cause only the apparition of pollution(Topcu and Canbaz, 2007).

Certain tile components find applications in cotto flooring, as well as in tennis courts, walkways, cycling paths, and gardens as ground materials(Topcu and Canbaz, 2007). Consequently, unused tile remnants are stockpiled in factory premises due to their economic worth. However, on an annual basis, around 250,000 tons of tiles become worn out, even as 100 million tiles are employed for repair purposes(Topcu and Canbaz, 2007). These waste materials can be recycled to save money(Topcu and Canbaz, 2007).

2.4 CERAMIC TILE WASTE AS AGGREGATE IN CONCRETE

The amount of tile waste on earth is enough for use as aggregate in concrete (Topçu and Canbaz, 2007). If recycled into aggregate, waste ceramic tiles aggregates (WCTAs) are relatively hard and have a substantial value of specific gravity, slightly lower water absorption, bulk density and higher voids, crushing value, impact value and abrasion value than the natural crushed stone(Senthamarai et al., 2005).

Concrete produced using ceramic waste as a replacement for natural aggregates, sand and cement can save enormous energy with considerable environmental benefits.(Pacheco - Torgal and Jalali, 2011).

2.5 PROPERTIES OF CONCRETE CONTAINING CERAMIC COARSE AGGREGATE

In the past few years, scientists and scholars have been extensively researching a vast field of study, focusing on comparing the mechanical and durability characteristics of concrete created with reclaimed aggregates versus those made with virgin aggregates. To

begin with, I.B. Topcu and M. Canbaz(2007) conducted a study that examined the integration of crushed tiles as a substitute for conventional aggregates in concrete. In the research, coarse aggregates ranging from 4mm to 32mm in size and typically consisting of crushed stones, were replaced with crushed tiles of similar average size at varying replacement ratios of 0%, 50%, and 100%. The results disclosed that the use of crushed tile aggregate(CTA) resulted in a 4% decrease in the unit weight of the concrete and resulted in a significant 40% decrease in both compressive and splitting tensile strengths. Furthermore, CTA had a detrimental impact on abrasion resistance and freeze-thaw durability. Ultimately, the research concluded that substituting 100% of coarse aggregates with CTA is not advisable.

W.M. Tawfeeq(2016) researched the impact of utilizing crushed tiles as a coarse aggregate in a concrete mixture. The research involved three distinct substitution percentages for crushed tile aggregates (0, 50, and 100%) within each replacement percentage. Additionally, variations in the water/cement and gravel/sand ratios were introduced as part of a parametric investigation to assess their influence on slump and compressive strength.

The findings of the study affirmed that an increment in the water/cement ratio resulted in an improve in workability but a reduction in the compressive strength of concrete mixes containing crushed tile aggregates. Furthermore, the results indicated that substituting crushed tiles for coarse aggregate at levels below 50% yields noteworthy enhancements in concrete properties.

Md. Daniyal and S. Ahmad(2015) investigated the application of waste ceramic tile aggregate in concrete. They investigated various substitution levels, including 10, 20, 30, 40, and 50% of traditional coarse aggregates replaced by crushed waste ceramic tiles.

The research findings indicated that the most favorable proportion of waste ceramic tiles to be added to the concrete mix, while maintaining a 0.5 water/cement ratio, was approximately 30%. Furthermore, the concrete with this optimal composition exhibited notable improvements in both compressive and flexural strength, with a 5.43% increment in compressive strength and a 32.2% increment in flexural strength in contrast with the reference concrete. These results highlight the beneficial impact of utilizing waste ceramic tiles on enhancing concrete properties.

S. O. Ajamu et al.(2018) studied the impact of replacement of coarse aggregate with ceramic tile waste on the strength characteristics of concrete. Various concrete samples were manufactured by incorporating ceramic tile waste (CTW) as a partial replacement for granite, ranging from 0% to 100% substitution. The test outcomes demonstrated that the workability of the mixtures improved as the CTW content increased, up to 30%, after which it declined. Additionally, a gradual reduction in the compressive strength of the tested specimens with an increment in the CTW content was noticed, reaching a minimal acceptable value of 20.03N/mm² at 28 days when 40% CTW was included. The water absorption rate of the samples also increased with higher CTW content, up to a 30% inclusion level. Consequently, based on these findings, it is recommended to use a concrete mix ratio that does not exceed 40% CTW content.

B.M.R. Marwein et al.(2016) investigated the utilization of ceramic waste in concrete. The primary aim of the research was to develop a standard-strength concrete by incorporating ceramic waste as a replacement for traditional coarse aggregates. Specifically, the ceramic waste utilized in this research consisted of broken tiles sourced from local stores. Various concrete mixtures, referred to as Ceramic Waste Concrete (CWC), were formulated with ceramic waste substitution percentages of 0%, 15%, 20%, 25%, and 30%. The concrete used in this investigation adhered to the M20 grade

specifications, and a consistent water/cement ratio of 0.48 was sustained across every concrete blends.

To assess the concrete's performance, several key properties were evaluated at different ages, including workability for freshly mixed concrete, compressive strength, modulus of elasticity and split tensile strength, for hardened concrete at intervals of 3, 7, and 28 days. The results of the research indicates that the optimal range for replacing conventional aggregate with waste tile aggregate falls within 5% to 30%. Additionally, it was observed that this replacement is suitable for ordinary concrete mixes, such as those conforming to M15 and M20 standards.

P. Rajalakshmi et al.(2016): A large bulk of ceramic tile change into wastage, and these waste materials are not reusable and recyclable due to their physical and chemical structure. Utilizing ceramic waste in concrete presents a promising solution for both environmental conservation and enhancing concrete properties. This research involves assessing the strength characteristics of concrete when incorporating waste ceramic tiles. Fine aggregate substitution with ceramic tile fine aggregates ranged from 10%, while coarse aggregate replacement ranged from 30%, 60%, to 100% by mass of M30 grade concrete. Concrete mixes were meticulously prepared, subjected to rigorous testing, and subsequently compared with traditional concrete to assess their strength. These evaluations were conducted over 7 and 28 days, revealing that waste ceramic tiles can serve as a viable replacement for conventional coarse and fine aggregates in concrete construction materials.

Prof. Shruthi H.G. et al.(2016) investigated the reuse of ceramic waste as aggregate in concrete. The research involved the integration of ceramic tile waste into concrete, replacing varying proportions of natural coarse aggregates, specifically 0, 10, 20, and

30%, while using M20 grade concrete. Subsequently, concrete molds were fabricated, and tests were conducted to evaluate both compressive and split tensile strength after 3, 7, and 28 days curing duration. The findings from the research revealed that the highest compressive strength was achieved when 30% of the ceramic tile aggregate was utilized as a substitute for natural coarse aggregate.

P.O. Awoyera et al.(2016) evaluated the mechanical characterization of ceramic waste aggregate (CWA) concrete, in an attempt to ascertain its suitability in construction. The research specifically examined the mechanical properties of concrete utilizing waste ceramic wall and floor tiles as aggregates. This investigation involved the separate replacement of both ceramic fine and coarse aggregates in traditional concrete, and the subsequent analysis of strength-related variables.

The results of the investigation indicated that the mechanical performance of CWA concrete improved with a rising percentage of natural aggregate replacement. In conclusion, the research suggested that concrete formulations utilizing CWA as a substitute for a portion of natural aggregates could be considered a viable substitute to standard concrete. Actually, in terms of strength, it was even deemed more favorable than traditional concrete.

V.Giridhar et al.(2015) investigated the influence of ceramic waste aggregate properties on strength of ceramic waste aggregate concrete. They created ceramic waste aggregate concrete (CWAC) by substituting traditional coarse aggregates with ceramic waste aggregates in varying proportions: 0%, 20%, 40%, 60%, 80%, and 100%. The research examined both the workability of freshly mixed CWAC and the strength of cured CWAC samples.

Their findings indicated a gradual decline in both workability and strength of the CWAC as the content of the ceramic waste aggregate replacing natural coarse aggregate increased. However, it is noteworthy that even with 100% substitution of traditional coarse aggregate with ceramic waste aggregate, the strength values of CWAC remained above the targeted mean strength of M20 grade concrete.

A research study conducted by A.M. Mustafa Al Bakri et al.(2013) examined the strength of concrete made with recycled ceramic waste as a substitute for traditional coarse aggregate. The main objective of the research was to assess the concrete's strength when incorporating ceramic waste as coarse aggregate. Concrete mixtures were formulated with a 28-day characteristic strength of 20 MPa, utilizing water-to-cement ratios of 0.4, 0.5, and 0.7. The study compared the strength development of these concrete mixtures incorporating 100% recycled ceramic waste aggregates to that of traditional concrete. The results indicated that concrete mixtures incorporating recycled ceramic waste aggregates exhibited strength levels ranging from 80-95% in comparison to traditional concrete. Consequently, this suggests that recycled ceramic waste holds promise as a suitable coarse aggregate substitute in concrete applications.

Prof. B. Rama Rao and CH. Anuradha(2016) performed an investigation to assess the impact of incorporating waste foundry sand and waste ceramic tiles as partial replacements for fine and coarse aggregates, respectively, in concrete. Waste foundry sand, a byproduct of metal casting industries, and waste ceramic tiles, remnants from construction activities, both pose environmental challenges when improperly disposed of. However, by integrating these waste materials into concrete, the issues associated with their safe disposal can be mitigated.

The experimental investigation involved producing concrete with varying proportions of waste foundry sand (WFS) ranging from 0% to 40% and waste ceramic tiles (WCT) ranging from 0% to 40% by weight, using M-25 grade concrete as the base. Tests were executed on both plastic and solidified states of the concrete to evaluate workability, compressive strength, and split tensile strength. Standard cubes and cylinders were used, and assessments were made at 7 and 28 days to ascertain the concrete's characteristics.

The findings revealed that the compressive and split tensile strengths of the concrete mixture increased with higher percentages of waste foundry sand and waste ceramic tiles, compared to conventional concrete. The optimum performance was observed at a 20% substitution rate, beyond which these strengths began to decrease. Furthermore, the workability of the concrete mix improved as the percentages of waste foundry sand and waste ceramic tiles increased in comparison to normal concrete.

In conclusion, this study demonstrates that waste foundry sand and waste ceramic tiles can be incorporated into concrete mixes. By adopting this approach, the challenges linked with the safe disposal of these waste materials can be significantly minimized.

P. Praneet Sai Kumar et al.(2018) conducted an investigation on the strength of concrete by partial replacement of coarse aggregate by ceramic aggregate. The primary objective of their investigation was to identify a viable alternative to traditional coarse aggregates and to provide empirical evidence regarding the impact of such substitution on concrete strength. The study utilized M30 grade concrete with a consistent 0.5 water/cement ratio. Various concrete mixtures were formulated by substituting the traditional coarse aggregates with ceramic aggregates at various substitution percentages including 20, 40, 60, 80, and 100%. These mixtures were then compared to a control mix. Key properties, including both compressive and tensile strength, were thoroughly investigated.

Following the completion of the experiment, the findings revealed that the highest compressive strength was achieved with a 20% substitution of coarse aggregates with ceramic aggregates, while the lowest compressive strength was observed with a 100% replacement. Additionally, the study showed that higher tensile strength was recorded when 40% of the coarse aggregates were substituted with ceramic aggregates, whereas lower tensile strength was evident at an 80% replacement level for coarse aggregates with ceramic counterparts.

S. Vinothkumar et al.(2019) investigated the characteristic strength of concrete by partial replacement with sawdust and waste ceramic tiles. Pulverized waste clay tiles were introduced into the concrete mixture to replace coarse aggregates, while sawdust was utilized as a substitute for fine aggregates at various substitution levels of 10, 20, 30, and 40%. The findings of this investigation unveiled that the incorporation of sawdust and fractured ceramic tiles as partial replacements for fine and coarse aggregates, respectively, yielded favorable effects on the concrete's compressive strength, with no detrimental consequences observed up to a 20% replacement threshold. Additionally, the study identified a notable reduction in weight for specimens containing 15% to 40% replacement. Nevertheless, due to the comparatively lower compressive strength in the case of 40% replacement, this particular substitution level is deemed suitable only for partition walls. Conversely, the 10% and 20% replacement levels are recommended, as they provide a substantial total weight reduction ranging from 5% to 10%. This research assumes particular significance in light of the growing scarcity of soil resources and offers viable solutions for the efficient utilization of waste materials.

P. Saravanakumar and D. Maruthachalam(2017) investigated the structural performance of recycled aggregate concrete incorporating waste clay tiles and fly ash. Their research explored the feasibility of utilizing waste materials, specifically clay tiles and fly ash, as

potential replacements for coarse aggregates and cement, respectively, in concrete compositions. Tests were executed on both freshly mixed and cured concrete specimens, incorporating partial substitutions of crushed granite coarse aggregates with broken tiles and cement with fly ash.

The findings revealed that concrete formulations having 20% and 30% tile aggregate (TAC) obtained compressive strengths of 82% and 75% in comparison to natural aggregate concrete (NAC). Moreover, when 25% of the cement was substituted with fly ash, there was a small decrease in strength at the early stages, but over time, the strength improved and eventually reached 85% and 79% of the compressive strength of natural aggregate concrete for 20% and 30% tile aggregate concrete, respectively. Similar trends were observed in the tensile and flexural strength of concrete mixtures incorporating tile aggregates. Consequently, these waste materials exhibit potential suitability for incorporation into concrete applications.

N. Taak et al.(2019) studied the strength parameters of concrete using marble slurry and ceramic waste aggregate as partial substitution of OPC-43 and coarse aggregate. The primary objective of their experimental work was to formulate recycled concrete (comprising marble powder and ceramic waste aggregate) by substituting a portion of OPC-43 with marble waste powder and substituting traditional aggregate with ceramic waste aggregate.

During the experimentation, various substitution ratios were employed. Specifically, different proportions of marble powder (10%, 20%, and 30%) were used to replace OPC-43, while coarse aggregate was substituted with ceramic waste aggregate at varying rates (20% and 40%). In all concrete mixtures, a constant water-binder ratio of 0.40 and a slump value within the limit of 50-90mm were maintained.

The outcome of the research indicates that the strength of the concrete exhibited a decreasing trend when the substitution levels of marble slurry and ceramic waste aggregate exceeded 20%. However, it should be noted that satisfactory results were obtained when these substitution levels remained below 20%.

S.B. Talavara and A. Vaddar(2021) examined the impact of substituting portions of cement and coarse aggregate with silica fume and ceramic tile waste. Silica fume, known for its pozzolanic properties, can induce pozzolanic activity in concrete. Conversely, ceramic tile waste, readily accessible in natural sources, serves as a micro filler material in concrete. Ceramic tile waste is both cost-effective and environmentally friendly, while silica fume carries a higher cost.

The research focused on assessing the performance of concrete when replacing varying percentages (0, 5, 10, and 15%) of cement and coarse aggregate in M40 grade concrete. The findings of the study indicated that the most favorable results in regards to compressive strength and flexural strength, were achieved with a 10% replacement rate. Specifically, the concrete exhibited a crushing strength of 41N/mm² and a flexural strength of 4.0N/mm², surpassing the values observed in standard concrete. Consequently, incorporating silica fume as a substitute for cement in concrete leads to enhanced strength properties.

V. Sharma et al. (2022) studied the use of waste ceramic as aggregate in concrete. During the experimentation phase, the conventional coarse aggregate in concrete was entirely substituted with waste ceramic aggregate having a size of 10mm. The concrete used was of M20 grade, with a 0.5 w/c ratio for the normal aggregate. However, for the concrete incorporating waste ceramic aggregate, a reduced w/c ratio of 0.3 was employed. This reduction was implemented with the intention of achieving higher

concrete strength, as it is already established that decreasing the water/cement ratio enhances concrete strength.

The study focused on evaluating various key characteristics of the concrete, including its workability when fresh and its compressive strength after hardening, at intervals of 3, 7, and 14 days. The findings of the research demonstrated the feasibility of producing concrete with substantial strength by incorporating ceramic waste as an aggregate. Notably, the compressive strength of the concrete incorporating ceramic waste exceeded that of the conventional concrete.

Consequently, in applications where M20 grade concrete is suitable, such as in domestic flooring and foundations (particularly for lighter structural loads), waste ceramic tiles can serve as a promising substitute for traditional aggregates in concrete. However, it should be noted that the reduced water-to-cement ratio in concrete containing waste ceramic aggregate negatively affected its workability when fresh. To address this issue, the study recommended the use of additives like super-plasticizers and silica fume during the mixing process to enhance workability.

J. Rajprasad et al.(2020) conducted an experimental investigation on partially additional of coarse aggregate with ceramic in concrete. The experiment involved using two types of ceramic waste materials, specifically tiles and flowerpots. They prepared M30 grade concrete with a 0.5 water/cement ratio and compared the strength properties of this concrete with that of conventional concrete.

The research examined the compressive strength and flexural strength of concrete mixes, varying the replacement of natural coarse aggregate with ceramic waste aggregate at percents of 0, 10, 20, 30, and 40%. The findings revealed that conventional concrete exhibited higher compressive and flexural strengths compared to any concrete containing

ceramic waste aggregate. Notably, the concrete with a 10% substitution of ceramic waste aggregate demonstrated strength characteristics closest to that of conventional concrete.

D.M. Peter et al. (2020) performed a research focusing on eco-efficient concrete that incorporates recycled ceramic waste aggregate (CWA). The primary aim of the investigation was to assess the characteristics of concrete when utilizing recycled ceramic waste aggregate.

During the investigation, traditional fine and coarse aggregates were partially replaced with ceramic waste aggregate at levels of 25, 50, and 75%. The research findings revealed that concrete samples incorporating 50% recycled ceramic fine aggregate and 75% recycled ceramic coarse aggregate exhibited higher compressive strength in contrast with conventional concrete. However, an increment in the recycled aggregate content led to a reduction in the modulus of elasticity.

As a consequence of aggregate replacement, the density of the concrete decreased, but it remained within the permissible limit while still achieving the desired level of compressive strength. This outcome highlights the potential for the use of ceramic tile waste as recycled aggregate materials, contributing to sustainable enhancement in concrete production.

The effects of using recycled ceramic material from sanitary installations on the mechanical properties of concrete was studied by I. Guerra et al. (2008) . In this investigation, conventional coarse aggregate materials in concrete was substituted with waste porcelain from sanitary installations at replacement rates of 3%, 5%, 7%, and 9%. They used M30 grade concrete and maintained a consistent 0.44 water/cement ratio across every concrete mixtures. The compressive strength of the concrete was determined at 7, 14, and 28 days.

The results of the investigation revealed that, regardless of the proportion of porcelain aggregate used in the concrete mix, the resulting concrete either maintained or improved its characteristic strength. Interestingly, the compressive strength of concrete containing porcelain aggregate exceeded that of conventional aggregate concrete, except in the case of a 3% substitution. This suggests that incorporating porcelain debris as a replacement for a portion of the coarse aggregates is a feasible option in terms of strength. Moreover, it offers a valuable opportunity for recycling residues from the construction industry.

The properties of concrete manufactured with the use of ceramic sanitary ware waste as aggregate was investigated by R. Grillo et al.(2019). The inevitability of waste generation is a common occurrence in various sectors, including construction and industries such as ceramic materials production, due to the utilization of multiple raw materials. Specifically, in the ceramic industry, one of the waste products that can be identified is ceramic scrap, notably from the sanitary ware sector.

With this context in mind, the primary objective of the study was to investigate the incorporation of ceramic scrap as a coarse aggregate in varying proportions, ranging from 25% to 100% by weight, as a replacement for traditional coarse aggregate. Several concrete properties were evaluated, encompassing the workability, adhesion, and porosity of fresh concrete, in addition to the compressive strength of hardened concrete, with curing periods of 7, 14, and 28 days.

It was noticed that concrete mixes containing 75% and 100% ceramic scrap aggregate displayed poor adhesion properties, while those with 25% and 50% ceramic scrap aggregate exhibited a slight water runoff, without compromising the workability of the concrete. In regards to the porosity, the concrete mixes containing 25%, 75%, and 100% ceramic scrap demonstrated lower values compared to the reference concrete.

Regarding compressive strength, all concrete mixtures achieved satisfactory average values, with the concrete containing 100% ceramic scrap also performing well. However, it's worth noting that the reference concrete exhibited the highest compressive strength at 48.44 MPa, while the concrete with 50% ceramic scrap aggregate displayed the lowest compressive strength at 44.72 MPa after a curing period of 28 days. It's noteworthy to mention that a super-plasticizer was employed in this research to enhance the concrete's properties.

H.M. Najm and S. Ahmad(2022) conducted an experiment on the mechanical and microstructural characteristics of concrete that incorporated waste ceramic materials. Their study aimed to determine the most effective utilization of ceramic powder and ceramic aggregates (both fine and coarse) as potential substitutes for ordinary Portland cement (OPC 43 grade) and traditional aggregates (both fine and coarse) in concrete.

The performance of this modified concrete was assessed through a series of experimental tests, including measurements of compressive strength, tensile strength, flexural strength, and torsional strength. The analysis of the waste ceramic concrete's mechanical properties revealed that incorporating ceramic waste materials as partial replacements for traditional aggregates, cement, and fine aggregates led to superior performance, particularly when using optimal percentages of 20% ceramic aggregate, 10% ceramic powder, and 10% ceramic fine aggregate in M25 grade concrete.

Furthermore, waste ceramic concrete exhibited enhanced morphological properties due to improved pore filling with dense and compact structures. This enhancement was accompanied by increased C-H crystal formation and a denser paste structure, all attributed to the inclusion of ceramic materials in the concrete mixture. These experimental results underscore the advantages of utilizing waste ceramic materials as

partial replacements in concrete production, offering economic, environmental, and technological benefits.

H.T. Tadesse(2020) conducted an investigation on the appropriateness of ceramic waste materials at Hawassa ceramic factory at Hawassa as partial replacement of conventional aggregate in concrete making. The experiment involved substituting both fine and coarse aggregates with ceramic scrap, with a 50% replacement for fine aggregate and a 33% replacement for coarse aggregate. The concrete used was of M25 grade, with a 0.52 water/cement ratio for the control concrete mix (M0), 0.43 for the concrete mix containing 33.3% ceramic scrap as a replacement for coarse aggregate (M1), and 0.45 for the concrete mix with 50% ceramic scrap replacing fine aggregate (M2). The study evaluated the workability of fresh concrete and conducted compressive strength tests on hardened concrete after 3 and 7 days of curing.

The findings indicated that the slump height for M0, M1, and M2 were 20mm, 8mm, and 0mm, respectively. Concerning compressive strength, the concrete mix M2 exhibited the highest strength values at both the 3-day and 7-day curing periods, while M0 and M1 showed compressive strength values of 20.15N/mm², 21.16N/mm², and 19.15N/mm², 24.16N/mm² at the 3-day and 7-day curing periods, respectively.

R.K. Goyal et al.(2021) investigated the optimum utilization of ceramic tile waste for enhancing concrete properties. The research focused on evaluating various aspects of concrete performance, including mechanical characteristics (such as compression, flexural, abrasion and tensile properties) and permeability when incorporating waste ceramic wall and floor tile aggregates. Additionally, the study assessed workability and density for different concrete mixtures.

The researchers employed crushed ceramic tiles as a replacement for traditional coarse aggregates in concrete, ranging from 0% to 25% replacement levels. A consistent water/cement ratio of 0.35 was maintained across every concrete mixes, with the use of a superplasticizer to obtain the preferred workability.

The findings of the experiment revealed that the most favorable mechanical results and desirable compaction factor were achieved when 15% of the ceramic waste was substituted in the cement concrete mix. The strength characteristics, including compression, tensile, and flexural properties, demonstrated improvement with the increment in ceramic tile aggregate content up to a 15% substitution level, beyond which a decline in strength was observed. Abrasion resistance showed a reduction with increasing ceramic waste content up to 15% replacement, but then abrasion depth increased. In terms of permeability, the ceramic waste-containing concretes exhibited higher permeability compared to the control specimen.

The research also noted a decrease in workability with the incorporation of ceramic waste, necessitating an increasing need for a water-reducing agent (superplasticizer) with higher levels of ceramic waste replacement. Additionally, both the fresh and hardened concrete densities were noticed to reduce as the ceramic waste content increased.

After reviewing multiple research studies, it can be concluded that the most favorable replacement percentage for traditional coarse aggregate with waste ceramic tile aggregate is 30% or lower. These findings indicate that using the appropriate replacement percentage of natural coarse aggregate with ceramic tile waste can enhance essential concrete properties, making it a viable construction material.

However, it's important to note that ceramic tiles created in various locations and climates may exhibit varying physical and mechanical characteristics. These differences

can significantly affect the quality of concrete made from these tiles. Therefore, it is advisable to conduct studies in different countries to ensure the reliability of concrete quality (Subedi et al., 2020).

While extensive research on the use of ceramic aggregate as replacement for coarse aggregate in concrete production has been conducted worldwide, limited research has been performed in Nigeria, especially concerning the durability of concrete containing ceramic aggregate. Hence, the primary objective of this research is to determine the compressive strength and durability properties of concrete made with ceramic aggregate and compare them to those of traditional aggregate concrete.

CHAPTER THREE

METHODOLOGY

3.1 GENERAL

This section of this study offers a comprehensive discussion of the supplies employed in this project and the procedures adopted to carry out the various activities. The discussion covers the nature, type, sources and properties of the materials, along with description of the various laboratory test conducted to accomplish the overall project.

3.2 MATERIALS FOR CONCRETE PRODUCTION

The materials used for the study includes:

1. Ordinary Portland cement (OPC)
2. Fine aggregate (Sharp sand)
3. Coarse aggregate (including granite and crushed waste ceramic tile)
4. Water

3.2.1 ORDINARY PORTLAND CEMENT (OPC)

The cement utilized for this research was an OPC of grade 42.5. It is a finely ground gray substance that when combined with water experiences hydration and transforms into a paste, effectively bonding the aggregate in concrete. The hydration action results in the hardening and setting of the concrete over time and can continue for an extended period, gradually strengthening the concrete as various compounds are formed.

The cement used for the project was obtained from a local shop at Isihor, Ugbowo, Benin-City

3.2.2 FINE AGGREGATE (SHARP SAND)

Fine aggregates consists of small, granular materials that helps to the fill the gaps between large particles(coarse aggragate), and plays a part in providing the overall strength and durability of concrete or mortar mixture. They are particles which falls in the range between 4.75mm and 150microns in size. The type of sand utilized for this research was sharp sand. The sand was obtained at a sand depot along Oluku, Benin - city.

Gradation test was performed on the sand in compliance with BS 812 : Part 103 : 1985

3.2.3 COARSE AGGREGATE

These consist of particles which are typically greater than 4.75mm in size. They have a vital function in providing strength and stability to the concrete mixture. Coarse aggregates are available in various sizes, shapes and material such as crushed stone, gravel, recycled concrete e.t.c. The choice of the suitable coarse aggregate type and size is determined by the particular demands of the concrete mixture and its intended use. The coarse aggregate utilized in this research comprises granite and waste ceramic tiles.

3.2.3.1 GRANITE

Granite is the natural coarse aggregate utilized for this research. It was also obtained from a local depot along Oluku, Benin - city, and it consist of stones of maximum size of 20mm.

Tests such as aggregate impact value and gradation test was executed on it in accordance with the respective standards in BS 812.



Figure 3.3: Granite

3.2.3.2 WASTE CERAMIC TILE AGGREGATE(WCTA)

Waste ceramic tiles was utilized as a substitute for granite in some of the concrete mixes of this study. It was obtained from a construction site and crushed into smaller pieces of an average size of 20mm using an hammer.

Gradation and aggregate impact value test was also executed on it, in compliance with the respective standards in BS 812.



Figure 3.4: Waste ceramic tile aggregate(WCTA)

3.2.4 WATER

Water have an essential function in the composition of concrete. It hydrates the cement particles, which initiates the chemical reaction to create a strong, solid material. It is crucial to exercise precise control over the water-to-cement ratio when mixing concrete, as too much or too little water can weaken the concrete or make the mix difficult to work with, respectively.

The water used for this study was sourced from the Civil/Structural Engineering Laboratory at the University of Benin. The water was unpolluted and was free of any content that could alter the rate of hydration.

3.3 CONCRETE MIX DESIGN

A mix design was prepared for M25 grade concrete employing the DOE(Design of Experiments) method. A mix ratio of 1:1.60:4.13 was obtained. This mixture was designed to attain a 25Mpa strength for the standard concrete after 28 days curing duration.

3.4 BATCHING OF MATERIALS

Batching involves calculating the quantities of the different components to be employed in a concrete mixture. The materials used for this research was batched in a ratio 1:1.60:4.13 for cement, fine and coarse aggregate respectively, for the various concrete mixes. Table 3.1 presents the outcome of the batching of the materials.

Table 3.1: Mix proportions

S/N	WCTA (%)	WATER (kg)	CEMENT (kg)	SAND (kg)	GRANITE (kg)	WASTE CERAMIC TILE ((kg)	W/C Ratio
1	0	1.53	3.06	4.91	12.64	0	0.5
2	10	1.53	3.06	4.91	11.37	1.26	0.5
3	20	1.53	3.06	4.91	10.11	2.53	0.5
4	30	1.53	3.06	4.91	8.85	3.79	0.5
5	40	1.53	3.06	4.91	7.58	5.05	0.5
6	50	1.53	3.06	4.91	6.32	6.32	0.5

3.5 LABORATORY TESTING OF THE PROPERTIES OF AGGREGATE

3.5.1 GRADATION TEST/PARTICLE SIZE DISTRIBUTION TEST

Particle size distribution means the range of different sizes of particles within a given sample of material. It provides information about the relative proportions of particles of various sizes in the material. The distribution is often represented as a graph or histogram where the x-axis represent particle size and the y axis shows the percentage or frequency of particles falling within each size range.

Sieve analysis is a common technique utilized to assess the particle size distribution of a granular material. Sieve analysis was performed on the aggregate including sand, granite and crushed waste ceramic tiles employed in this research, in compliance with BS 812: Pat 103 : 1985

3.5.1.1 OBJECTIVE

- a. To ascertain the particle size distribution of the various aggregates employed in the study.
- b. To plot grading curves representing the particle size distribution of the various aggregates utilized in the investigation.

3.5.1.2 APPARATUS

1. A temperature-regulated ventilated oven, maintaining a consistent temperature of $105 \pm 5^{\circ}\text{C}$.
2. Two weighing balances, one with a capacity of around 5 kilograms, providing accuracy up to 1 gram, and the other with a capacity of approximately 500 grams, accurate to 0.1 gram.

3. Test sieves of sizes 20mm, 14mm, 10mm, 8mm and 5mm for coarse aggregate, and 2.36mm, 2.00mm, 1.18mm, 600, 425, 300, 212 and 150 microns for fine aggregate.
4. A receiving pan
5. A metal tray/head pan
6. A cleaning brush
7. Clock.

3.5.1.3 PROCEDURE

1. A quantity of the specified sample enough to carry out the experiment is collected and subjected to heating at a temperature of $105 \pm 5^{\circ}\text{C}$ to achieve a dry mass and then allowed to cool.
2. The sieve to be used are cleaned to remove any leftover particles stuck in the openings, and then arranged in an increasing order beginning with the smallest size sieve i.e 150 microns sieve for fine aggregate and 5mm sieve for coarse aggregate.
3. A quantity of the oven dried aggregate is emptied into the topmost sieve and the aggregate is sieved by subjecting the stack of sieves or a set of sieves containing the aggregate to different motions including backward and forward, right and left, circular clockwise and anticlockwise motion e.t.c by hand shaking.
4. After sieving, the topmost sieve is removed from the stack of sieves and its content i.e the fraction of the aggregate retained on the sieve after sieving is emptied in a container, weighed and its value recorded.
5. The same operation is then repeated for all other sieves in the stack and their various content weighed and recorded.

3.5.2 AGGREGATE IMPACT VALUE (AIV) TEST

The aggregate impact value (AIV) test is a technique used to assess the impact resistance of aggregate, which are materials like crushed stone, gravel or sand used in construction.

The test serves as a quality control measure for highway pavements, assessing whether aggregate are suitable for use in constructing roads. The aggregate needs to possess strength to withstand abrasion, crushing and impact loads to ensure their effectiveness in road construction.

The test involves dropping a metal hammer into a sample of the aggregate and determining the percentage of the fines generated from the broken pieces. A lesser AIV indicates better resistance to impact, which is important for construction of durable roads and structures.

Aggregate impact value (AIV) test was performed on the coarse aggregates i.e granite and crushed waste ceramic tile aggregate employed in this research, in compliance with BS 812-112: 1990

3.5.2.1 OBJECTIVE

1. To ascertain and compare the impact resistance of granite and crushed waste ceramic tile aggregate
2. To plot a graph representing the impact resistance of granite and crushed waste ceramic tile.

3.5.2.2 APPARATUS

1. The impact testing machine which consist of
 - a. A circular metal base

- b. A cylindrical steel cup
- c. A metal hammer
- d. Means for raising the hammer
- e. Means for supporting the hammer
2. 14mm and 10mm square-hole perforated plate test sieves
3. A cylindrical metal measure.
4. A tamping rod
5. A balance of capacity not less than 500g readable to 0.1g
6. A well-ventilated oven
7. A rubber mallet
8. A metal tray
9. A brush with stiff bristle

3.5.2.3 PROCEDURE

1. A representative sample passing through a 14mm sieve and retained in a 10mm sieve is collected and oven dried at a temperature of $105 \pm 5^{\circ}\text{C}$ for a period of not more than 4 hours, after which it is allowed to cool to room temperature before testing
2. The testing machine is set up, ensuring it is levelled and rigid.
3. The dry sample is filled into the steel cup in three layers, each layer being evenly tamped with 25 strokes of the tamping rod. Excess aggregate is removed by rolling the tamping rod across and in contact with the top of the steel cup.
4. The aggregate in the steel cup (M1) is measured and its value is recorded, then the aggregate is transferred to the cylindrical steel cup of the impact machine.

5. The cylindrical steel cup is affixed in the metal base of the impact machine and the sample in the steel cup is subjected to 15 blows by releasing the hammer to fall freely from a fixed height ($380 \pm 5\text{mm}$).
6. The crushed aggregate is carefully removed from the cylindrical steel cup and sieved through a 2.36mm sieve. The mass of the aggregate passing and retained in the 2.36mm sieve (M2 and M3 respectively) is weighed and recorded to the nearest 0.1g
7. The aggregate impact value (AIV) is then calculated using equation 3.1.

$$\text{AIV} = \text{M2}/\text{M1} \times 100 \quad (3.1)$$

Where AIV is aggregate impact value(%), M2 is mass passing 2.36 mm sieve in g and M1 is mass retained in 2.36mm sieve in g.

3.6 TESTING THE PROPERTIES OF FRESH CONCRETE

3.6.1 SLUMP TEST

The slump test is a standard test utilized to determine the consistency and workability of freshly mixed concrete. It offers insight into the suitable timing for placing, compacting, and forming the concrete.

The test entails filling a cone - shaped mold with concrete, compacting it, and then determining the change in height of the concrete after the mold is taken off. This change in height is known as the “slump”. The slump value helps concrete workers and engineers ascertain if the concrete mix has the preferred properties for the intended construction project.

Slump test was performed on the freshly mixed control and ceramic aggregate concrete used in this study, in accordance to BS 1881-102:1983.

3.6.1.1 OBJECTIVE

1. To determine and compare the workability of the freshly mixed control and waste ceramic aggregate concrete.

3.6.1.2 APPARATUS

1. A measuring tape
2. A slump cone
3. A base plate
4. A tamping rod

3.6.1.3 PROCEDURE

1. A representative sample of freshly mixed concrete is taken from the batch being used for casting.
2. The slump cone is subsequently placed and supported in position on the non-absorbent, levelled surface base plate, after which the cone is filled with the concrete sample in three equal layers, with each layer being compacted by subjecting each layer to 25 blows using a tamping rod.
3. After filling and compacting, the surplus concrete is removed from the top of the mold, ensuring a smooth and levelled surface.
4. The mold is carefully lifted vertically from the concrete and set at the side of the shaped concrete, allowing the concrete to spread/slump due to its own weight.
5. A measuring tape is then used to measure the variation in height between the height of the mold and the highest point of the slumped concrete. The difference is referred to as the "slump".

3.7 CASTING OF CUBES

The concrete samples was casted in compliance with the specification of BS 1881-3:1970. Mixing of the concrete was carried out using a concrete mixer in order to attain a high degree of consistency of the concrete mixes. The mixed concrete was transferred to a lubricated wooden mould of dimension 100x100x100mm and compacted on a concrete vibrator machine. The excess concrete was stuck off from the top of the mold, and the concrete's surface was smoothed utilizing a trowel to attain a smooth levelled surface. The concrete was allowed to harden for 24hours, after which it was cured in water for 7 and 28days.

A total of 54 cubes sample of M25 concrete was casted for this study.

3.8 CURING OF CASTED CONCRETE CUBES

Concrete curing is an action of maintaining adequate moisture, temperature and time conditions to ensure the optimal hydration of cement particles in a concrete mixture. This process allows the concrete to develop its desired strength, durability and other properties over time. Proper curing helps prevent cracks, improves the concrete's overall quality and ensures that it reaches its intended design strength.

There are different curing methods available including curing by immersion, steam curing, water curing, curing curing by sealing e.t.c. The choice of curing methods depends on factors such as project size, weather conditions, available resources and the desired concrete properties.

The curing method used for this study was curing by immersion. After demolding, the different concrete specimens were completely immersed in water, in a curing tank

present at the structural lab in the Civil/Structural Engineering Department at the University of Benin. The concrete samples were cured for a period of 7 and 28days.

3.9 COMPRESSIVE STRENGTH TEST

The compressive strength test is a method employed to ascertain the capacity of a material, like concrete, to resist axial loads (compression) without breaking or failing. It involves applying a steadily increasing load to a specimen until it collapses, allowing engineers and researchers to assess the material's strength and sustainability for various application in construction, engineering and other fields.

Compressive strength test was executed on the different solidified concrete mixes (i.e 0%, 10%, 20%, 30%, 40%, and 50%) of this study. On the 7th and 28th day curing period of each concrete mixes, 3 cubes for each concrete mixes were taken out from the curing tank and crushed in a compressive strength test machine to ascertain their strengths. This was executed in compliance with specification of BS 1881-116:1983.

3.9.1 OBJECTIVE

1. To ascertain the compressive strength of the different concrete mixes
2. To compare the compressive strength of the different concrete mixes.

3.9.2 APPARATUS

1. Compression testing machine (CTM)
2. Weighing balance

3.9.3 PROCEDURE

1. The concrete cubes are taken out from the curing tanks, dried using cloth to remove the surface water, and then weighed.

2. The concrete cubes is subsequently positioned in the compression testing machine, ensuring it is centered in the lower plate of the compression test machine.
3. The upper plate of the compression machine is fastened to the top of concrete cubes, and then loading is applied and increased continuously at a nominal range until failure of concrete cubes occurs.
4. The maximum load applied to the concrete cubes is thereafter noted and the compressive strength computed using equation 3.2.

$$C.S = P/A \quad (3.2)$$

Where C.S is compressive strength(N/mm²), P is maximum load applied (N) and A is Area (mm²)

3.10 DURABILITY TEST

The purpose of conducting durability tests on concrete is to ascertain its ability to withstand physical and chemical degradation. This degradation can arise from interaction with the environment (Physical deterioration) or interaction among the components that make up the concrete (chemical deterioration).

Some common durability tests includes, water absorption test, carbonation test, freeze - thaw resistance test, Abrasion resistance test e.t.c. These test ensure that concrete structures can endure the challenges posed by the environment reducing maintenance and extending service life.

3.10.1 WATER ABSORPTION TEST

Water absorption test for concrete is employed to ascertain the porosity of concrete, which is essential for understanding its durability and potential for water related issues. The test involves immersing dried concrete samples in water and measuring the weight

gain over time. This information helps engineers and builders ascertain the resistance of concrete to water penetration and its overall quality. Lower water absorption generally correlates with better durability and longer lasting concrete structures.

For this study, water absorption test was executed on the various hardened concrete mixes to ascertain their durability in accordance to specifications of BS 1881 - 122 : 2011

3.10.1.1 OBJECTIVE

1. To determine and compare the durability of traditional aggregate concrete and concrete with ceramic tile aggregate.

3.10.1.2 APPARATUS

1. A ventilated drying oven, regulated to retain a temperature of $105^{\circ}\text{C} \pm 5^{\circ}\text{C}$.
2. A balance capable of weighing specimens up to 5kg to an accuracy of 0.001kg
3. Dry airtight vessel
4. Curing tank

3.10.1.3 PROCEDURE

1. On the 28th day curing period, three specimens of each concrete mixes are placed in a drying oven and allowed to dry for 72hours.
2. On removal from the oven, the three specimens are left to cool in a dry airtight vessel for 24hours. After which their masses is weighed and recorded
3. The concrete specimens are then completely immersed in a tank containing water, at a depth at which there is $25\text{mm} \pm 5\text{mm}$ of water above the top of the specimen.
4. The three specimens are immersed in water for 24 hours, after which they are removed and dried using a cloth until all free water is wiped off from the surface.

5. Each specimen is then weighed and their masses noted.
6. The water absorption of each concrete specimen is then computed utilizing equation 3.3.

$$W.A = (M1 - M2)/M1 \times 100 \quad (3.3)$$

Where W.A is water absorption(%), M1 is mass of the specimen when dry (kg) and M2 is mass of specimen after immersion.

CHAPTER FOUR

RESULTS AND DISCUSSION

Tests was conducted on the aggregates, fresh concrete and hardened concrete utilized for this research, to ascertain their various physical characteristics. The results of these test are discussed below.

4.1 SIEVE ANALYSIS

Sieve analysis was conducted to ascertain the gradation of the sand, granite and waste ceramic tile aggregate used for this research. From the results presented in table 4.1, 4.2 and 4.3 for sand, granite and waste ceramic tile aggregate respectively, it can be observed that the sand consist of particles mainly retained in the 212 microns sieve, while granite consists of aggregates of an average and maximum size of 14mm and 20mm respectively. Lastly, waste ceramic tile aggregate consist of aggregates of an average and maximum size of 20mm.

Overall, it can be said that the aggregates used for this study is well graded and therefore suitable for used in concrete production.

Table 4.1: Sieve analysis for sand

S/N	Sieve sizes	Average weight retained(g)	Weight Retained (%)	Cumulative weight retained (%)	Cumulative passing(%)
1	2.36 mm	5.2	1.0	1.0	99
2	2.00 mm	3.0	0.6	1.6	98.4
3	1.18 mm	21.9	4.4	6.0	94
4	600 microns	99.2	19.8	25.8	74.2
5	425 microns	28.9	5.8	31.6	68.4
6	300 microns	56.8	11.4	43.0	57
7	212 microns	207.0	41.4	84.4	15.6
8	150 microns	37.1	7.4	91.8	8.2

9	Pan	40.9	8.2	100	0
10	Total	500	100		

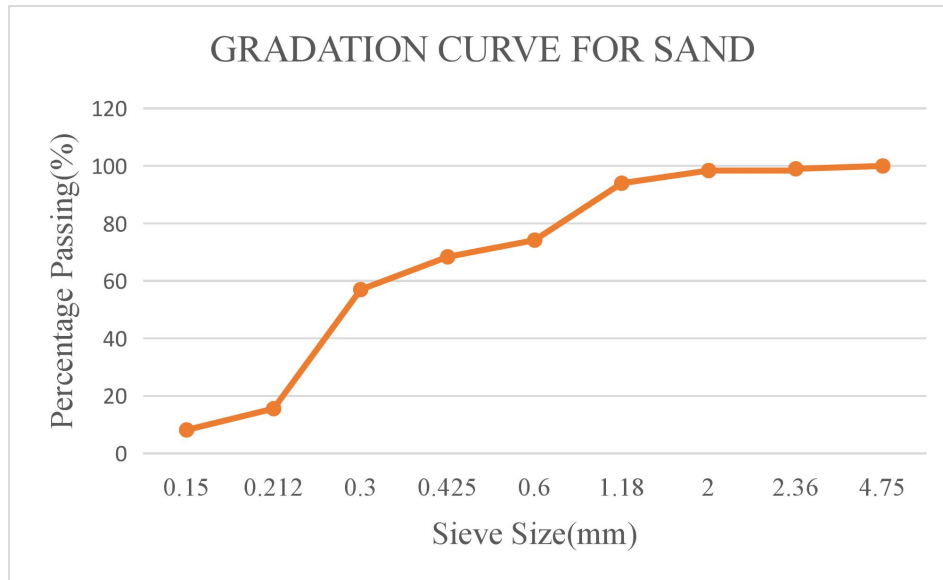


Figure 4.1: Gradation curve for sand

Table 4.2 : Sieve analysis for granite

S/N	Sieve sizes (mm)	Average weight retained(kg)	Weight retained (%)	Cumulative weight retained(%)	Cumulative passing(%)
1	37.5	0.000	0	0	100
2	20	0.924	30.8	30.8	69.2
3	14	1.425	47.5	78.3	21.7
4	10	0.606	20.2	98.5	1.5

5	8	0.037	1.2	99.7	0.3
6	5	0.002	0.1	99.8	0.2
7	Pan	0.006	0.2	100	0
8	Total	3.000	100		

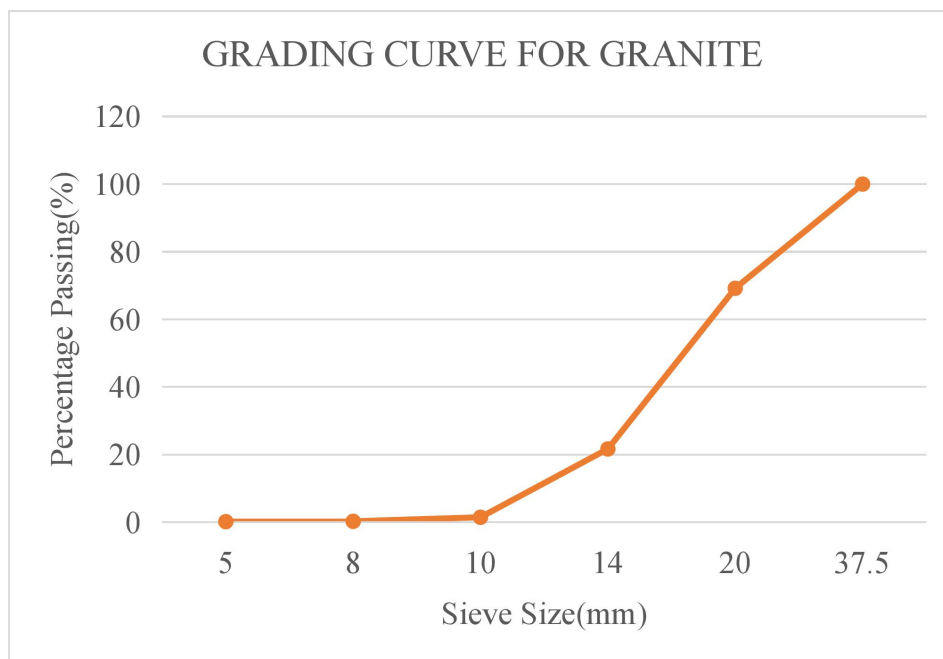


Figure 4.2: Gradation curve for granite

Table 4.3 : Sieve analysis for waste ceramic tile aggregate

S/N	Sieve size(mm)	Average weight retained (kg)	Weight retained (%)	Cumulative weight retained(%)	Cumulative passing(%)
1	37.5	0	0	0	100

2	20	1.634	54.5	54.5	45.5
3	14	1.180	39.3	93.8	6.2
4	10	0.171	5.7	99.5	0.5
5	8	0.012	0.4	99.9	0.1
6	5	0.003	0.1	100	0
7	Pan	0	0		
8	Total	3	100		

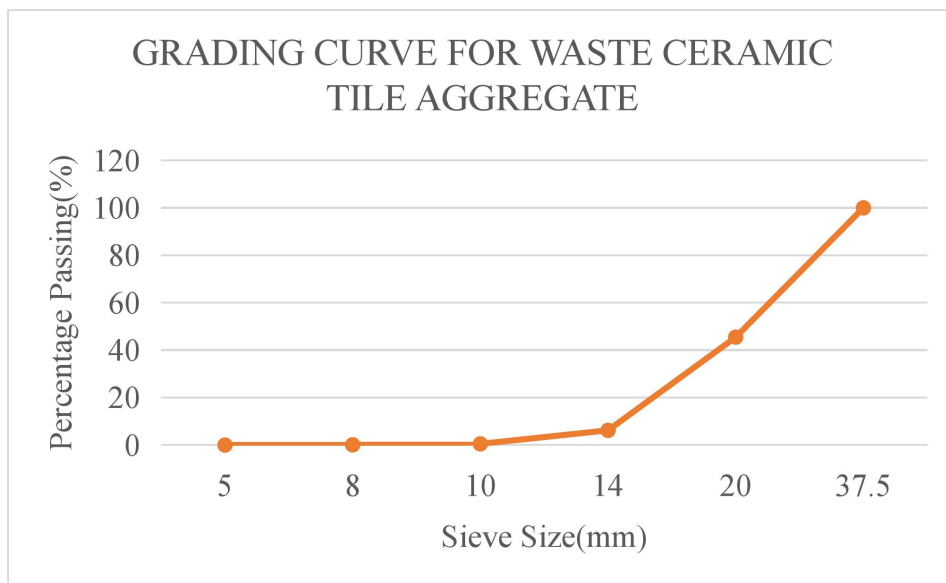


Figure 4.3: Gradation curve for waste ceramic tile aggregate

4.2 AGGREGATE IMPACT VALUE (AIV) TEST

Aggregate impact value test was utilized to compare the opposition to sudden impact load of the granite and waste ceramic tile aggregate used for this study. The results for both aggregates (granite and waste ceramic tile aggregate) were found to be 26.43% and

23.51% respectively, which are within the permissible range according to BS 812-112:1990. However, waste ceramic tile aggregate shows a better performance than granite, thereby having a better impact resisting capacity than granite.

Table 4.4: Aggregate impact value(AIV) test for granite

S/N	Description	Sample 1	Sample 2	Sample 3
1	Total weight of dry sample(M1)(g)	348.41	350.49	345.07
2	Weight of portion passing 2.36mm seive(M2)(g)	90.19	93.63	92.13
3	Aggregate impact value $((M2/M1) \times 100)(\%)$	25.89	26.71	26.70
4	Average aggregate impact value(%)	26.43		

Table 4.5: Aggregate impact value(AIV) test for waste ceramic tile aggregate

S/N	Description	Sample 1	Sample 2	Sample 3
1	Total weight of dry sample (M1) (g)	276.42	275.25	275.67
2	Weight of portion passing 2.36mm sieve(M2)(g)	66.75	64.17	63.58

3	Aggregate impact value $((M2/M1) \times 100)(\%)$	24.15	23.31	23.06
4	Average Aggregate impact value(%)	23.51		

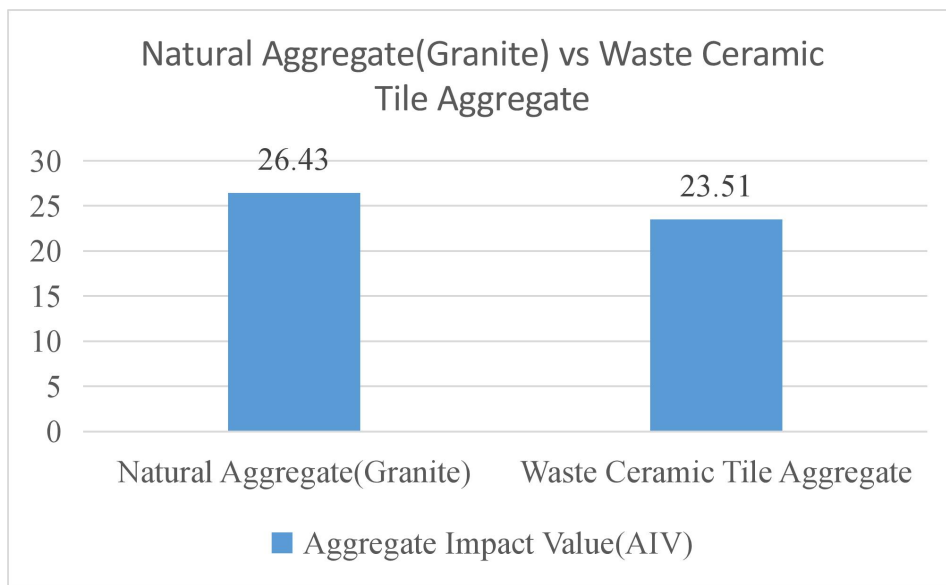


Figure 4.4: Aggregate Impact value(AIV) of granite and waste ceramic tile aggregate

4.3 SLUMP TEST

Slump test was performed on the different freshly mixed concrete mixes to determine their workability. From the result presented in table 4.6 below, a decrease in slump with an increment in waste ceramic tile aggregate content is noticed. The control mix of 0% ceramic waste aggregate content is observed to have the maximum slump value of 14mm, while the least slump value of 5mm is observed for the concrete mix with 50% waste

ceramic tile aggregate content. This reduction in slump value can be ascribed to the higher water absorption capacity of the waste ceramic tile aggregate.

Table 4.6: Slump test

S/N	Type of mix	WCTA(%)	Slump(mm)
1	NAC	0	14
2	WCTAC10	10	13
3	WCTAC20	20	10
4	WCTAC30	30	10
5	WCTAC40	40	7
6	WCTAC50	50	5

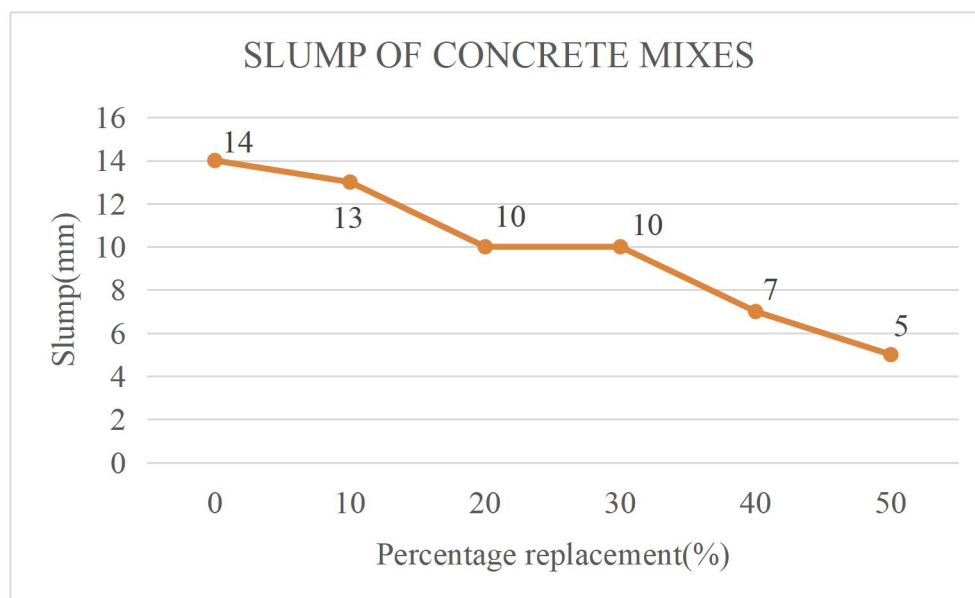


Figure 4.5: Slump of concrete mixes

4.4 COMPRESSIVE STRENGTH TEST

This test was executed on the various concrete mixes to ascertain their compressive strengths. Concrete cubes of 100×100×100mm size were utilized for the test on the 7th and 28th day curing period. The result presented in table 4.7 shows an increase of 19%, 10.41%, 13.515, 4.17% in the 7th day compressive strength for 0%, 10%, 20%, 30% and 40% substitution. While a decrease of 3.99% is observed for 50% substitution.

For the 28th day compressive strength, an increment of 0.47%, 7.69%, 13.25% is observed for 10%, 20% and 30% substitution when contrasted with the control concrete. While a decrease of 0.034% and 6.27% is observed for 40% and 50% substitute.

10% substitution shows the greatest 7th day compressive strength with an increment of 19% over the control mix, while the greatest 28th days compressive strength was noticed for 30% substitution with an increment of 13.25% over the control mix.

Hence, to make a concrete with at least a similar compressive strength as that of a concrete incorporating granite as coarse aggregate, a 40% substitution with waste ceramic tile aggregate should not be exceeded.

Table 4.7: Compressive strength test

S/N	MARK	Age (Days)	Weight (kg)	Failure load (KN)	Compressive strength (N/mm ²)	Average compressive strength (N/mm ²)	
1	NAC	7	2.503	202.34	20.23	21.32	
2			2.554	217.35	21.74		
3			2.566	220.04	22.00		
4		28	2.585	290.28	29.03		29.66
5			2.598	306.35	30.64		
6			2.550	293.20	29.32		
7	WCTAC 10	7	2.593	270.71	27.07	25.37	
8			2.563	240.51	24.05		
9			2.532	249.89	24.99		
10		28	2.546	306.95	30.70		29.80
11			2.570	312.32	31.23		
12			2.533	274.56	27.46		
13	WCTAC	7	2.488	252.62	25.26	23.54	

14	20		2.468	215.59	21.56	
15			2.536	238.10	23.81	
16		28	2.489	330.02	33.00	31.94
17			2.496	285.00	28.50	
18			2.529	343.07	34.31	
19	WCTAC 30	7	2.508	219.95	22.00	24.20
20			2.546	235.65	23.57	
21			2.499	270.25	27.03	
22		28	2.480	291.47	29.15	33.59
23			2.472	346.16	34.62	
24			2.498	369.86	36.99	
25	WCTAC 40	7	2.421	245.43	24.54	22.21
26			2.386	199.87	19.99	
27			2.506	221.08	22.11	
28		28	2.452	310.48	31.05	29.65
29			2.386	277.43	27.74	
30			2.450	301.48	30.15	

31	WCTAC 50	7	2.301	207.04	20.70	20.47	
32			2.263	195.26	19.53		
33			2.310	211.76	21.18		
34		28	2.221	273.07	27.31		27.80
35			2.350	264.36	26.44		
36			2.411	296.53	29.65		

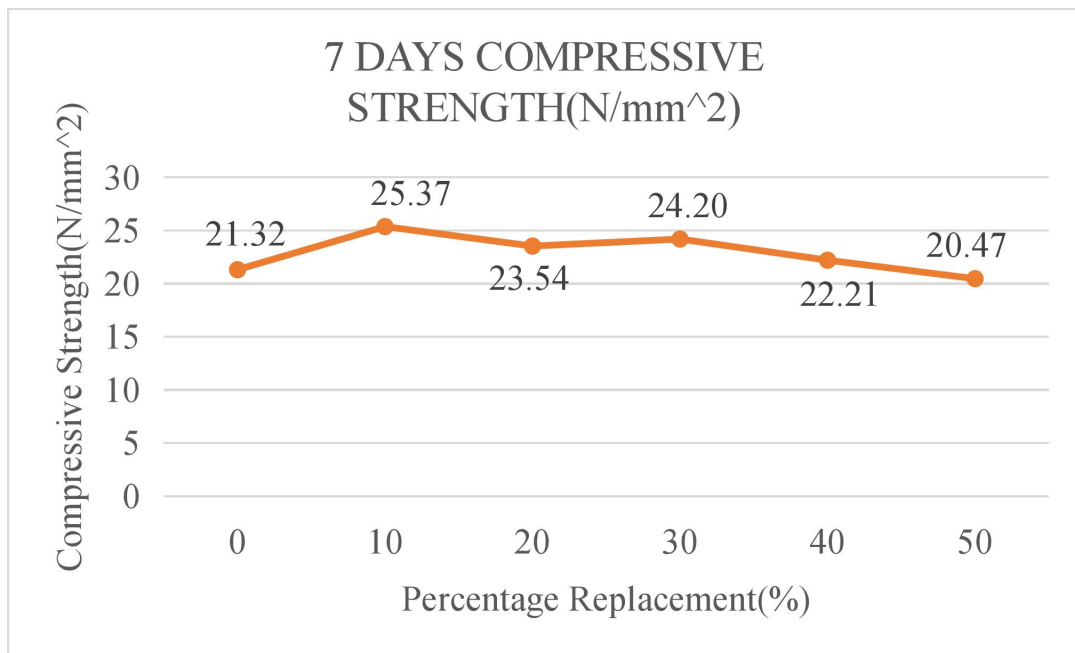


Figure 4.6: 7 Days compressive strength of concrete mixes

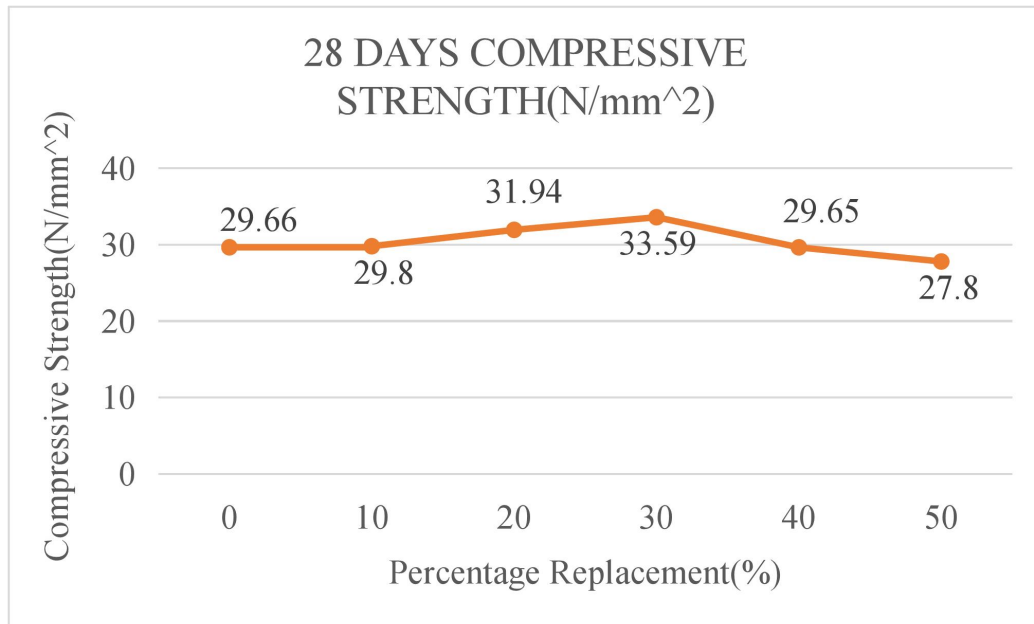


Figure 4.7: 28 Days compressive strength of concrete mixes

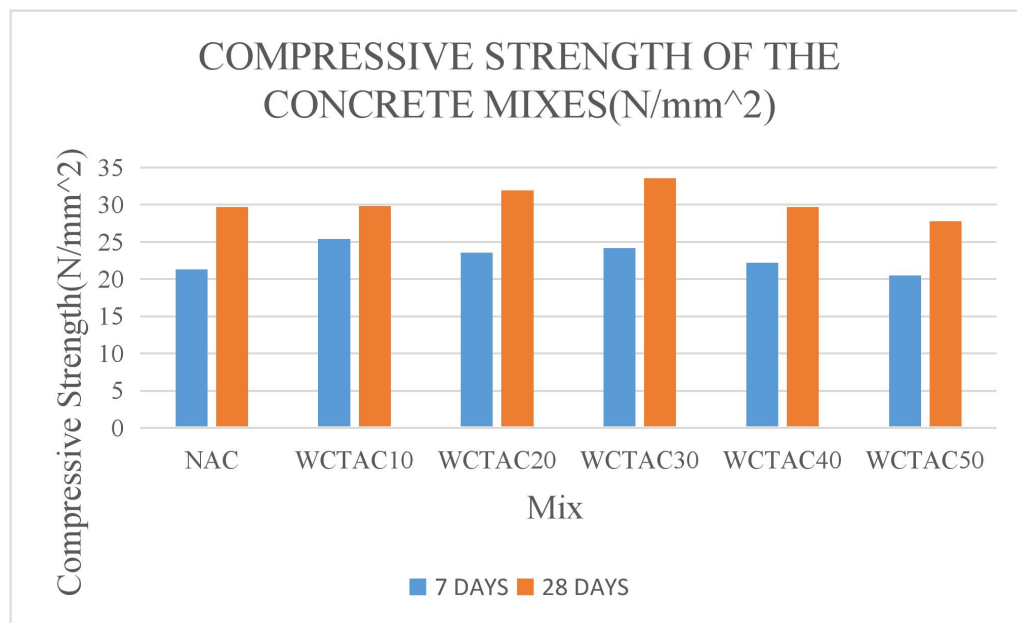


Figure 4.8: Comparison between 7 and 28 days compressive strength

4.5 WATER ABSORPTION TEST

Table 4.8 presents the outcomes of a water absorption test carried out on the various concrete mixes of this study. The test is aimed to assess the percentage water absorbed

by the different concrete mixes and hence compare the durability of the concrete mixes. The result presented in table 4.8 reveals a decrease in the water absorption of 6.36%, 30.51%, 16.10% and 9.32% for 20%, 30%, 40% and 50 % substitution respectively, in contrast to the control concrete of 0% substitution. While an increase of water absorption of 4.66% is observed for 10% substitution. This variation in water absorption can be ascribed to the difference in the porous nature of the various concrete mixes.

It can therefore be said that 20-50% substitution of granite with waste ceramic tile aggregate reduces the water absorption of the concrete mixes, while 10% substitution with waste ceramic tile aggregate increases the concrete's water absorption.

Table 4.8: Water absorption test of the concrete mixes

S/N	Mix	Oven dry weight (A) (kg)	Saturated surface dry weight (B) (kg)	Percentage water absorbed $((A-B)/A) \times 100$	Average Percentage water absorbed (%)
1	NAC	2.530	2.591	2.41	2.36
2		2.535	2.591	2.21	
3		2.519	2.581	2.46	
4	WCTAC 10	2.499	2.558	2.36	2.47
5		2.471	2.528	2.31	
6		2.483	2.551	2.74	

7	WCTAC	2.466	2.530	2.60	2.21
8	20	2.444	2.510	2.70	
9		2.483	2.516	1.33	
10	WCTAC	2.472	2.501	1.17	1.64
11	30	2.461	2.525	2.60	
12		2.452	2.480	1.14	
13	WCTAC	2.390	2.445	2.30	1.98
14	40	2.415	2.460	1.86	
15		2.428	2.471	1.77	
16	WCTAC	2.370	2.423	2.24	2.14
17	50	2.357	2.411	2.29	
18		2.394	2.439	1.88	

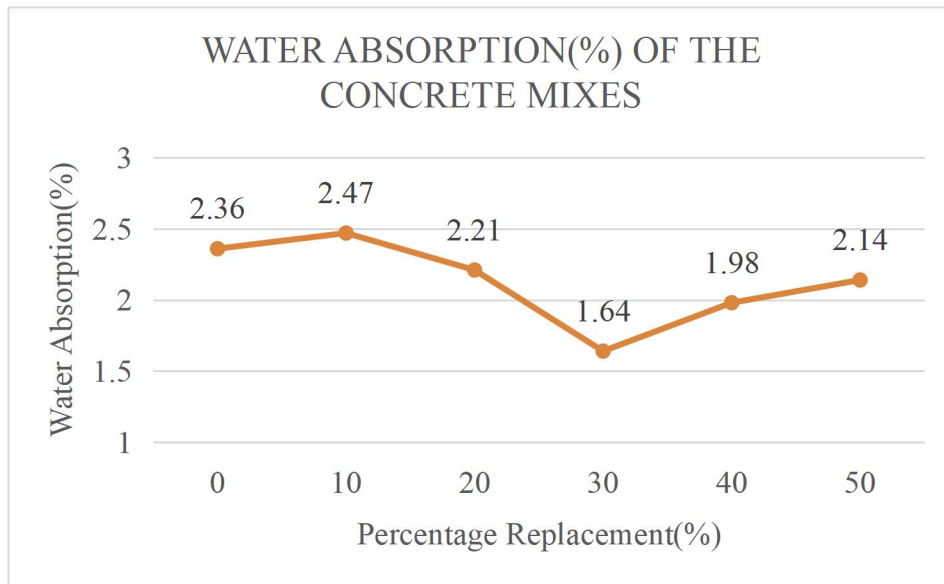


Figure 4.9: Water Absorption(%) of the concrete mixes

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The objective of this research was to explore the feasibility of substituting granite with waste ceramic tile aggregate in structural concrete. The following findings emerged from the conducted investigations:

1. Gradation can be achieved for waste ceramic tile aggregate by manually crushing the ceramic tiles using hammer.
2. Both coarse aggregates (i.e granite and waste ceramic tile aggregate) used for this study, are equally capable of withstanding significant impact loads. However, waste ceramic tile aggregate has a higher resistance to impact loads when compared to granite.
3. Owing to the comparatively higher water absorption capacity of waste ceramic tile aggregates, an increase of the percentage of the waste ceramic tile aggregates in the concrete mixes results in a decrease in the workability of the fresh concrete mixes.
4. Comparatively, a higher 7th and 28th day compressive strength is obtained when substituting 10-30% of granite with waste ceramic tile aggregate as opposed to the control mix containing 0% ceramic aggregate. A similar 28th day compressive strength is achieved with 40% substitution.
5. 10% substitution of granite with waste ceramic tile aggregate leads to an elevation in water absorption. While 20-50% substitution reduces the concrete mixes water absorption, with 30% substitution having the least water absorption. Hence, 20-50%

replacement of granite with waste ceramic tile aggregate improves the durability of concrete.

6. Waste ceramic tile obtained from construction and demolition sites, as well as ceramic manufacturing industries can be repurposed and utilized as coarse aggregate in concrete.

5.2 RECOMMENDATIONS

1. Substitution of granite with waste ceramic tile aggregate should be limited to 40% in concrete production. However, for optimal strength and durability for structural concrete, a 30% substitution of granite with waste ceramic tile aggregate is recommended.

2. Appropriate chemical admixtures could be employed to enhance the workability of concrete incorporating waste ceramic tile aggregate.

5.3 Areas for further research.

1. Further structural performance test like the flexural strength of concrete incorporating different percentages of ceramic tile coarse aggregate should be analyzed.

2. Investigations should also be conducted to explore the impact of incorporating chemical admixtures to enhance the workability of concrete that includes ceramic tile coarse aggregate.

3. An economic viability of utilizing waste ceramic tile aggregate in producing concrete should be investigated by comparing the cost savings/ advantages associated with using ceramic waste aggregate against traditional aggregate in concrete production.

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890-898.

APPENDIX

Sieve analysis for sand: Weight retained(g) for three samples

Sieve sizes	Sample 1 (g)	Sample 2 (g)	Sample 3 (g)	Average weight retained (g)
2.36 mm	4.9	5.3	5.4	5.2
2.00mm	2.7	3.0	3.2	3.0
1.18mm	22.0	22.4	21.2	21.9
600 microns	103.3	97.2	97.0	99.2
425 microns	27.8	28.9	30.1	28.9
300 microns	55.4	57.7	57.4	56.8
212 microns	206.2	207.1	207.6	207
150 microns	36.8	37.6	37.0	37.1
Pan	40.9	40.8	41.1	40.9
Total				500

Sieve analysis for Granite: Weight retained(g) for three samples

Sieve sizes	Sample 1 (kg)	Sample 2 (kg)	Sample 3 (kg)	Average weight retained (kg)
37.5	0	0	0	0
20	0.818	1.050	0.905	0.924
14	1.603	1.290	1.382	1.425
10	0.540	0.616	0.661	0.606
8	0.029	0.034	0.048	0.037
5	0.002	0.002	0.003	0.002
Pan	0.008	0.008	0.001	0.006
Total				3.000

Sieve analysis for waste ceramic tile aggregate(WCTA: Weight retained for three samples

Sieve sizes	Sample 1(kg)	Sample 2(kg)	Sample 3(kg)	Average weight retained(kg)
37.5	0	0	0	0
20	1.650	1.550	1.703	1.634
14	1.182	1.243	1.114	1.180

10	0.158	0.186	0.168	0.171
8	0.005	0.017	0.014	0.012
5	0.005	0.004	0.001	0.003
Pan	0	0	0	0
Total				3



Figure A - 1: A stack of sieves



Figure A - 2: Student carrying out sieve analysis of the waste ceramic tiles aggregate



Figure A -3: Aggregate impact value machine



Figure A - 4: Student placing fresh concrete in a mould



Figure A - 5: Student levelling the surface of a compacted fresh concrete



Figure A- 6: Hardened concrete samples



Figure A - 7: Student carrying out compressive strength test on the hardened concrete samples



Figure: A- 8: Concrete samples in an oven for water absorption test