

**MECHANICAL PROPERTIES OF CONCRETE WITH PULVERIZED GLASS
AS PARTIAL SUBSTITUTE OF FINE AGGREGATE**

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PLAGIARISM

This report on the “**MECHANICAL PROPERTIES OF CONCRETE WITH PULVERIZED GLASS AS PARTIAL SUBSTITUTE OF FINE AGGREGATE**” was prepared and compiled by **ONAIWU, Emmanuel Idemudia**, Mat No. **ENG1905282**, a student from the department of Civil Engineering (Structural Engineering Programme), Faculty of Engineering, University of Benin City, Edo State, Nigeria. Has PASSED the PLAGIARISM TEST.

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DEDICATION

Above all, I dedicate this project to Jehovah God for everything that He has done for me, especially for His protection, guidance, and provision throughout this project and my time at this prestigious university. I also want to thank my mum, Mrs. Onaiwu faith Osagioduwa for helping me with my schooling.

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ABSTRACT

This study aims to investigate the potential of using pulverized glass as a partial substitute for fine aggregate in concrete, focusing on how it affects the mechanical properties of the resulting composite. By exploring various replacement levels of pulverized glass, the project identified an optimal balance that enhances both the sustainability and performance of concrete.

An experimental work was performed to study the slump, unit weight, compressive strength, dry density and water absorption of concrete partially substituted with pulverized glass. A concrete mix with a target mean strength of 20N/mm² was designed using a standard 1:2:4 mix ratio. Pulverized glass was used to partially replace the fine aggregate at replacement percentages of 0%, 5%, 10%, and 15% in accordance to relevant literature. The concrete was then cast into cubes and allowed to cure for 7, 14, and 28 days at room temperature in a laboratory.

The results indicate that workability increases with higher pulverized glass content, with slump values rising from 30 mm for the control mix to 46 mm at 15% replacement. However, compressive strength generally decreased as the replacement percentage increased. The 5% replacement mix achieved the highest compressive strength among the modified mixes, with an average 28-day strength of 19.72 N/mm² compared to 20.68 N/mm² for the control mix. Nine concrete mixes were examined using discarded glass in place of 0%, 5%, and 15% of the weight of sand. The study concludes that, crushed glass can substitute up to 5% of fine aggregate in concrete, which helps lessen the effects of sand mining. This concrete can be regarded as eco-friendly since it uses less raw materials and has fewer negative environmental effects.

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ABBREVIATIONS AND ACRONYMS

AASHTO: American Association of State Highway and Transportation Officials

ASTM: American Society for Testing Materials

BS: British standard

MRF: Material Recycling Facilities

ASR: Alkali-Silica Reaction

WG: Waste glass

GA: Glass Aggregate

GP: Glass Powder

RGS: Recycled glass sand

SF: Silica Fume

FA: Fly ash

GBFS: Granulated Blast Furnace Slag

PC: Portland Cement

GGC: Green Glass Content

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Study

Reusing used glass is a significant concern in many nations because of the rise of solid waste in the environment. Glass is regarded as a significant solid waste that is present in most nations worldwide. Its presence causes environmental issues and is not much impacted by weather (Caijun *et al.*, 2007). Therefore, it is necessary to identify appropriate ways to address this issue. In order to demonstrate the potential of using waste glass as a building material and substituting it partially in the concrete mixture without compromising the quality of the concrete, important research has been done. As a result, concrete can be made with suitable qualities. The goal of many investigations is to substitute a specific percentage of crushed waste glass for fine aggregate in the concrete mixture. These studies also examine the potential use of waste glass as a partial or complete substitute for traditional concrete materials, which has two benefits. The first is that it lessens the depletion of nature's resource riches. The second is lowering environmental hazards by creating glasscrete, a type of unconventional concrete.

Unlike other inert materials, glass may be recycled repeatedly without losing its chemical composition. Unfortunately, a large amount of glass becomes unsuitable for recycling; the effectiveness of this procedure is influenced by a number of factors. First, how well do different glass hues be collected and sorted? If different colours (such clear, green, amber, etc.) are mixed together, they can't be used to make new glass containers. Second, the amount of contaminants that may be present in the stockpile has an impact, followed by the cost of shipping. since not every city in a nation has a recycling factory. Thus, the main aim of environmental authorities is to reduce, as far as possible, the disposal of post-consumer glass in landfill or recycle to glass products. Therefore, it has been supposed

that, if glass could be incorporated in concrete production, it would greatly reduce the disposal of waste glass or its use in lower valued works such as fill or road base materials (Shayan, 2002). The main issue with using glass in concrete, however, is the alkali-silica reaction, which occurs when silica-rich glass particles (glass aggregate) react with the alkali in cement (Shao *et al.* 2000).

1.2 Statement of The Problem

Around the world, there has been a lot of interest in using recovered waste glass in concrete. Sadly, post-consumer glass makes up a significant amount of solid waste, and because it can be challenging to find suitable markets that would accept glass collected for recycling, its presence and buildup have had an adverse effect on the environment. The United States released over 9.2 million metric tons of post-consumer glass in 1994. Over 100,000 tons of glass waste are collected each year in New York City alone, with container glass accounting for the majority of this waste. According to Chesner *et al.* (1997), the Material Recycling Facilities Company (MRFC) pays up to \$45 per ton for the disposal of these wastes. These factors make research on the impacts of employing waste glass necessary to determine whether it may be used in place of waste glass as a fine aggregate in concrete.

However, the main issue with using glass in concrete is the chemical reaction known as the alkali-silica reaction (ASR), which occurs between the silica-rich glass particles (glass aggregate) and the alkali in cement. This reaction creates gel, which causes swelling when moisture is present, expansions, and concrete deterioration. This study's primary goal is to examine the properties of concrete that contains finely crushed glass and determine the ideal proportion of finely crushed glass to produce concrete with desirable qualities.

1.3 Aim and Objective of The Study

The primary aim of the project is to assess the feasibility and environmental impact of partially replacing traditional fine aggregate with pulverized glass thereby reducing waste disposal and promoting sustainable construction practices.

Objectives of Study

1. To evaluate the feasibility of using recycled glass as a partial replacement for fine aggregate in Concrete.
2. To assess the environmental benefits of reducing waste glass disposal through Its use in concrete production.
3. To investigate the effects of recycled glass on the mechanical properties of Concrete

1.4 Scope of Study

The Scope of work will include the following:

1. Specific gravity of the fine and Coarse aggregate
2. Particle Size distribution of both the fine and Coarse aggregate used in the experiment.
3. Compressive strength of the blended Concrete cubes
4. Evaluate the technical, environmental and economic benefits of using recycled glass in concrete production.
5. Bulk density test of the concrete.
6. Water absorption test of the concrete.

1.5 Justification of Study

The justification for this study lies in the growing need to enhance the sustainability and environmental performance of construction materials. Concrete, as a widely used construction material, contributes significantly to resource depletion and environmental pollution. The extraction of natural aggregates, such as sand, leads to ecosystem degradation, while the production of cement results in high carbon emissions. Given the global challenges surrounding these issues, there is a critical need to explore alternative, sustainable materials to reduce the environmental footprint of concrete production.

By investigating the mechanical properties of concrete with pulverized glass as a partial substitute for fine aggregates, this study aims to address these concerns. Pulverized glass, a material that is often discarded as waste, can be recycled and used effectively in concrete. This research seeks to explore whether the use of pulverized glass can maintain or improve the strength, durability, and workability of concrete while contributing to resource conservation and waste reduction.

Through this study, we aim to provide valuable insights into the potential benefits of utilizing recycled glass in concrete, including reduced reliance on natural resources, cost-effectiveness, and the reduction of waste that would otherwise contribute to landfill accumulation. Ultimately, this research will contribute to the development of more sustainable construction practices, promoting environmental protection while maintaining the performance standards required in modern concrete applications.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter provides an overview of some of the existing research on the use of waste glass in both construction and non-construction settings, with a particular emphasis on the use of waste glass as cementitious material and fine aggregates in the concrete system. The potential alkali-silica reaction and typical strategies to lessen its negative effects are given a lot of attention.

2.1 General application of wastes glass

Sadom and Mizi (2014) investigated the use sustainable replacement for fine aggregate in concrete. It shows that concrete strength and durability improved with the addition as of water glass, workability is maintained despite a decrease in slump. The compressive tensile and flexural to 18.38% with 20% waste glass content. The concrete structure became denser and more consistent.

Anand and Yogesh (2021) studied showed the utilization of waste glass powder as a cementitious material in concrete glass content. In the work, they tested the effect of replacing cement with waste glass powder (WGP) on concrete properties. Whereby replaced cement with waste glass powder at 10%, 20% and 30% ratios. By evaluating the workability density and compressive strength following the industry standards and guidelines (BIS, ASTM, DOE). With the aim to explore the potential use of waste glass poulder as a sustainable supplementary cementitious material.

Eric *et al.* (2014) investigated on the mechanical behaviour of concrete containing crushed waste glass. In the research, 12 different concrete mixes were prepared with a unique combination of materials. The crushed waste glass (glasscrete) was used to replace the fine aggregate (sand) in varying percentages (5-20%). Highly reactive metakaolin. (HRM) was

added as a mineral admixture in different percentage (0-18%). The optimal dosage of water reducing admixture (WRA) was determined using slump test. The Compressive strength tests were performed on 144 cube specimens at 3, 7, 14 and 21 days. While the Splitting tensile strength test were conducted 144 Cylinder Specimen at, 3, 7, 14 and 21 days. It was showed in the experiment glass aggregate negatively affected compressive Strength due to lower adhesion and bonding strength with paste.

Lavanya *et al.* (2023) studied showed that evaluating the mechanical performance of waste glass powder fine aggregate substitute to enhance sustainability in concrete production. In the work, waste glass powder (WGP) was used as a partial substitute for fine aggregate (sand) in concrete production. The experiment used different proportion of WGP (10%, 20%, 30% and 40%) to replace sand in concrete mixes. The results showed that up to 20% WGP substitution workability Increased but then decreased up to 30% WGP substitution, compressive strength split tensile strength and WGP Substitution led to a marginal reduction in cost. In conclusion, WGP can be used as a partial substitute for fine aggregate up to 30% without compromising strength. It improves workability and strength Characteristics of concrete.

Kavyateja *et al.* (2016) showed that why crushed glass as a replacement for fine aggregate (sand) in concrete production. In the work, the compressive strength of concrete increased with the use of glass up to 20% replacement level. The workability also increased with increasing the crushed glass content, while the split tensile strength decreased with increase in crushed glass content. In conclusion, the study promoted the use of crushed glass as a sustainable and cost-effective alternative to sand in concrete production.

Lalitha *et al.* (2017) conducted a comprehensive review on the strength and durability of concretes incorporating recycled crushed glass as replacement for fine aggregates. Their findings suggest that fine aggregates can be successfully replaced with crushed glass in

concrete production. The use of crushed glass with larger particle sizes may exacerbate alkali-silica reactions, whereas finer particle size may mitigate this issue. The combination of finer crushed glass particles with mineral admixtures, such as fly ash, can further reduce alkali-silica reaction. Finally, pozzolanic properties continuously increase with decreasing size with the glass powder.

Aper *et al.* (2020) studied showed the effect of glass sand on the properties of concrete and determine the optimum amount of waste glass aggregate that can effectively replace fine aggregates in cement concrete. The experiment used Portland limestone cement, crushed granite and river sand with varying percentage of glass sand replacement ranging from 0%, 5%, 10%, 15%, 20%, 30%, and 40%. The result showed that glass have no significant effect on the workability and density. The compressive strength Increased with glass sand content up to 10% replacement then decreased. The optimal replacement percentage is 16% for achieving the strength of 25N/mm². In conclusion, waste glass can be effectively used as a fine aggregate replacement in concrete thereby providing a sustainable alternative.

Hameed *et al.* (2024) studied showed the use of Iron ore tailing as fine aggregate with glass fibre in concrete. They were five mix types used in the experiment which are control mix (CM), 15% Iron ore tailing (M1), 25% Iron ore tailing (M2), 33% Iron ore tailing (M3) and optimized Iron ore tailing with 0.5% glass fiber (M4). The result showed that optimum replacement percentage of Iron ore tailing is 15%. While compressive strength of M1 is 10.4% lower than CM but M4 achieved similar strength to CM, split tensile strength of M1 and M4 is Increased by 8.1% and 10.12%. respectively compared to CM. Water absorption and chloride penetration increase with Iron ore tailing replacement. In conclusion, partial replacement of Iron ore tailing with fine aggregate is a promising solution for disposal and conservation of natural resources.

Karthik and Suresh (2024) studied examined the effect of replacing fine aggregate with glass waste particle (GWP) on concrete properties. In the research, 135 Specimen were cast including cubes, cylinder and prism. Glass waste particles replaced fine aggregate from 0% 40% in interval of 10%. The tests were conducted on 7th, 14th, and 28 days to determine compressive split tensile and flexural strength. In the results, workability increased with increasing GNP replacement, while compressive strength increased by 11.3% at 28days with 30% replacement. The split tensile strength also increased by 3.4% at the 28 days with 30% GNP replacement. The flexural strength also increased by 7.2% at the 28 days with 30% GNP replacement. In conclusion, the study results contributed to the growing body of research on sustainable concrete production, highlighting the potential for GNP to reduce environmental impacts and waste management costs.

Dinesh *et al.* (2017) investigated the use of recycled glass as a replacement for fine aggregate in concrete production. The study showed the environmental benefits of why recycled glass, including reduced waste management issues and conservation of natural resources. The experimental investigations replaced fine aggregate with crushed glass in varying percentage (0%, 20% 40%, 60% 80% and 100%) and evaluate the compressive strength, Split tensile strength and flexural strength of the concrete. The results show improved strength and durability with the use of crushed glass with a mix proportion of 60% glass and 40% fine aggregate yielding the best results. The research concludes that recycled glass can be successfully used as a good replacement for fine aggregate in concrete production offering a sustainable and environmentally friendly solution.

Elavarasan and Dhanalakshmi (2016) studied showed on waste glass as a partial replacing material in concrete for fine aggregate. The studies to the work, waste glass can effectively replace fine aggregate up 20% resulting in improved compressive and tensile strengths. Specifically, a 10% replacement level yields a 3.3% increase in compressive strength,

while a 20% replacement level. yields a 39.55% increase in split tensile strength. This sustainable approach reduces the exploitation of natural resources, minimizes environmental impacts associated with river sand mining and decreases the risk water table reduction, bridge pier sinking and river bed erosion. In conclusion, using waste glass as fine aggregate offers a viable and eco-friendly solution for the construction industry warranting further adoption and standardization.

Vijayakumar et al (2015) investigated on the utilizing of glass powder as partial replacement of cement in concrete production. The research revealed that finely ground glass powder could replace up to 30% of cement without adverse effect, improving thermal properties and aesthetic appeal. The key findings indicated that 20- 40% glass powder replacement increased compressive Strength by 19.6-33.7%, Split tensile strength by 44% and flexural strength by 83.07- 100%. Additionally, optimal glass powder dosage ranges and particle size were identified to minimize alkali-silica reaction. In conclusion, incorporating waste glass into concrete production proved to be a viable solution for enhancing sustainability and mechanical properties, significantly reducing environmental impact and conserving natural resources.

Olutoge (2016) studied showed the expect of waste glass powder on the mechanical properties of concrete. The researched involved preparing concrete mixes with 0%, 10%, 20% and 30% WGP replacement levels, using a 1:2:4 mix ratio and 0.6 water to binder ratio. Test conducted included slump, compressive strength (7, 14, 21 and 28 days) and flexural strength (28 days). The result showed decreasing slump value and lower compressive and flexural strengths with increasing WGP replacement. The control mix exceeded target strengths while 10% WGP replacement demonstrated impressive strength. The study concluded that WGP can partially replace cement in concrete but optimal level

and long-term effects require further study offering a sustainable solution to reduce environmental impacts.

Josmar and Josette (2012) investigated on the utilization of imploded glass on structural concrete. The research utilized mixed waste glass, crushed or imploded to replace to 40% of Portland cement. The results showed that 40% replacement yielded concrete with adequate properties while 10-20% replacement exhibited high resistance to chloride ion penetration making it suitable for coastal structures. The implosion method produced sharper contaminant free particles approving handleability. The findings suggest that incorporating waste glass in concrete can reduce environment impacts and conserve resources, warranting further research into optimal replacement levels and long-term expect.

Matos and Sousa-coutinho (2012) investigated the durability of mortar using waste powder as cement replacement. The experiment involved using commercial type I Portland cement, silica fume and waste glass from car windscreens, which was crushed and ground. It was characterized particle size distribution, X-ray diffraction and chemical composition analysis. The results showed that WGP meets ASTM C 618 and European standards for pozzolanic materials which exhibits good pozzolanic reactivity and aligns with soda lime glass in chemical composition. However, the compressive Strength may be lower with WGP replacement. In conclusion, incorporating waste glass powder as partial replacement material in cement-based application offers a sustainable solution.

Tiwari and Patel (2014) studied showed the strength and workability of different grade of by partial replacement of fine aggregate by crushed brick and recycled glass. In the research, the feasibility of using brick powder and glass powder as fine aggregate replacement in concrete production. The result showed that optimal replacement of sand with brick powder is 20% and with glass powder is 15% with compressive strength higher

than concrete. However, workability decreases with increasing brick powder content and increase with glass powder content. Overall, the study concludes that brick powder and glass powder can be effectively used as sustainable alternatives to fine aggregate in concrete thereby conserving natural resource, reducing environmental impact and promoting waste management.

Geutam *et al.* (2012) investigate the use of waste glass as a fine aggregate replacement in concrete has gained attention due to its potential environmental and economic benefits. Studies have shown that crushed glass can exhibit characteristics similar to gravel or sand making it a viable alternative. In the experimental results, it indicates that replacing fine aggregate with 10-20% waste glass can increase compressive strength at 7 and 28 days, with the optimal replacement levels ranging from 10-20%. The use of waste glass in concrete also reduces production cost and promote sustainable waste management. Overall, waste glass can be effectively used as a fine aggregate replacement, offering a better solution for the construction industry environmental and economic challenges.

Federico and Chidiac (2009) studied showed that waste glass as a supplementary cementitious material in concrete. In the experimental results, by replacing fine aggregate with 10% waste glass increased compressive strength by 47.75% at 7 days and 3.30% at 28 days. At 20% replacement the strength increased by 13.64% at 7 days and 2.18% at 28 days. However, strength decreases marginally at 30-40% replacement level. The study concluded but waste glass can effectively replace fine aggregate with optimal replacement level of 10% and we can reduce production cost and promote sustainable waste management in the construction industry.

Turgut and Yahlizade (2009) studied explored replacing fine aggregate with fine glass (FG) and coarse glass (CG) in concrete paving blocks. Seven mixtures with 10-30% replacement levels were tested for strength, weight, absorption and abrasion. The result

showed that 20% FG replacement increased compressive strength by 69% while the flexural strength by 90% and splitting tensile strength by 47% with 15% improved abrasion resistance. The study concludes that fine glass can effectively replace fine aggregate at 20% by weight enhancing mechanical and physical properties while suppressing alkali-silica reaction offering a sustainable waste management solution and reduced production cost.

Jani and Hoyland (2014) conducted an experiment to evaluate the potential use of waste glass in the production of cement and concrete. The results demonstrated that waste glass possesses physical properties comparable to natural sand, notably lower water absorption rate. While the study identified alkali-silica reaction (ASR) as a significant concern when incorporating waste glass as an aggregate. They found that optimizing waste content to 10-20% enhanced replacement aggregate level not only enhance compressive strength but also yielded environmental benefits. The study concluded that integrating waste glass into cement and concrete production offers a sustainable solution that conserves natural resources, reduces energy consumption and CO₂ emissions, while providing an environment responsible for waste management.

Topcu and Canbaz (2004) study examined the viability of utilizing waste glass as aggregate in concrete production by replacing calcareous crushed stone aggregate in concrete production by replacing calcareous crushed stone aggregate with 0%, 15%, 30%, 45% and 60% waste glass. They discovered that waste glass addition decreased unit weight, slump and compressive strength up to 49% at 60% waste glass. While increasing the flow table value. The flexural strength, indirect tensile strength, Schmidt of hardness, ultrasonic velocity and dynamic modulus of elasticity also decreased. The researchers concluded that waste glass affects workability and strength properties.

Nath and Rajendian (2023) investigated the feasibility of using waste glass powder as a cement substitute and precious slag balls (Polystyrene balls) as fine aggregate substitutes in concrete production. The experiment revealed that optimal glass powder replacement was 20% thereby improving compressive strength 11.5% and flexural strength by 16.67%. While split tensile strength showed marginal improvement at 10-15% GP. Polystyrene balls substitution from 10-25% increased the workability and the compressive strength where the peak strength is at 20%. The durability test demonstrated enhanced the resistance to acid, alkaline and sulphate attacks. The key findings highlighted glass powder high pozzolanic nature, and void filling propensity, polystyrene balls spherical shape and low water absorption which contribute to improve the strength and workability. In conclusion, the study demonstrated that 20% GP and 20% polystyrene balls can be effectively used as substitutes in concrete production thereby enhancing mechanical properties and durability.

Jain et al. (2020) investigated on the durability performance of waste granite and glass powder added to concrete. The experiment revealed that GP and GrP additions approved compressive strength by up to 34%, reduced permeability and water absorption and enhance the durability against acid, sulphate and chloride attacks. The key findings highlighted the pozzolanic properties of glass powder and granite powder leading to a dense matrix formation and improved the mechanical properties. SEM analysis confirmed the dense matrix XRO analysis indicated the formation of beneficial mineral compounds. The optimal GP/GrP blend to 15/30 mixes achieved superior compressive strength of 36.85 N/mm² and durability. In conclusion, incorporating waste glass and granite powder as partial replacements in concrete production offers a sustainable solution enhancing strength, durability and environmental benefits while addressing solid waste management concerns. This innovative approach has significant potential for Construction application.

Aliabdo *et al.* (2016) study explored the feasibility of utilizing waste glass powder in the production of cement and Concrete. The investigation revealed that glass powder exhibits properties meeting Class F and C standards and the inclusion enhanced concrete compressive strength, tensile strength and density. A 10% replacement of cement with glass powder boosted mortar compressive strength by 9% while optimal replacement level of 10% cement substitution and 15% cement addition were adopted. The study revealed that glass powder refines concrete microstructure reduces water absorption and decreases void ratio. These findings underscore the potential of glass powder to improve concretes durability and sustainability. In conclusion, glass powder in concrete production offers a sustainable solution to enhance performance reduce environmental waste and promote eco-friendly construction practices.

Hamza *et al.* (2017) researched on the use of cement base grout with glass powder for deep mining. The study varied glass powder proportion of 3%, 6%. and 9%. Then the clay moisture contents of 21%, 31% and 36% with also conducting Vicat unconfined compressive strength and ultrasonic pulse velocity tests. The results showed increased setting times and enhanced unconfined compressive strength and ultrasonic pulse velocity values with glass powder addition particular at higher replacement ratios. The findings indicate that glass powder improves treated clay soil mechanical properties while minimizing environmental impact and costs. In conclusion, incorporating glass powder in cement-based grout offers a viable eco-friendly solution for deep mixing in soft clay soils enhancing performance while promoting sustainability.

Bajad *et al.* (2011) studied showed the effect of glass on the strength of concrete subjected to sulphate attack thereby examining its resistance. The investigation replaced cement with glass powder in increments 5-40% and assessed compressive and flexural strength with and without sulphate exposure. The Study revealed that replacing 20% of cement with

glass powder yielded optimal results thereby increasing compressive strength by 30% and flexural strength by 22% beyond the threshold strength decreased. Sulphate exposure reduced strength by 2-17% but glass powder pozzolanic properties and void filling capabilities enhanced the resistance. This sustainable approach offers potential for construction application leveraging waste glass powder to improve concrete durability and reduce environmental waste.

Bhupinderjeet and Ritesh (2018) investigated on the use of waste powder and aggregate as partial replacements in concrete replacing cement from 10-40%, fine aggregate from 10-40% and Coarse aggregates from 5-30%. The result showed compressive strength increased up to 20% replacement with glass powder with improved flexural and tensile strength, workability and density. The key findings include that glass powder pozzolanic properties reduced alkali-silica reaction, improved its durability and environment benefits from reduced cement consumption and waste glass disposal. The optimal replacement level was 20% glass powder and 30% crushed glass. In conclusion, waste glass powder can effectively replace traditional materials in concrete thereby enhancing strength and sustainability.

Yahia *et al.* (2017) investigated the impact of fly ash and waste glass powder on concrete compressive strength and workability. The study replaced cement with 10-20% fly ash and waste glass powder. Then cube and cylindrical samples were tested at 7 and 28 days. The results revealed that 10% fly ash increased compressive strength by 53% at 7 days and 31% at 28 days, while 10% waste glass had minimal impact. However, 20% fly ash and waste glass significantly reduce the strength. The finding highlighted fly ash benefits in enhancing workability reducing water, demand and improving durability and waste glass ability to reduce segregation. In conclusion, adding 10% fly ash enhance concrete strength and durability whereas excessive fly ash or waste glass leads to substantial decrease.

Hossam *et al.* (2019) studied showed that using glass powder as cement replacement in concrete testing 0-30% glass powder and two mixing methods. Initially, glass powder increased slump and decreased density then reducing early age compressive strength. However, after 90 days, 20% glass powder achieved the highest strength. A new mixing method dissolving glass powder in water significantly outperformed conventional with 10% GP increasing compressive strength by 130%. The study concludes that optimal 10-20% glass powder replacement and the new mixing method can significantly enhance concrete strength and sustainability offering a promising eco-friendly alternative.

Ashay *et al.* (2009) stated that there is a need to find the new alternative material to replace the river sand such that excess river erosion and harm to environment is prevented. Many major materials are finding different materials to replace sand and one of the major materials is quarry stone dust. Using different proportions of these quarry dust along with sand the required Concrete mix can be obtained. This paper presents a review of the different alternatives to natural Sand in preparation of mortar and concrete. The paper emphasizes on the physical and mechanical properties and strength aspect of mortar and concrete.

Belachia *et al.* (2011) used the recycled aggregates of the making of hydraulic concrete. Properties like density, workability, compressive strength and flexural strength of the hydraulic concrete were found and compared with the properties of conventional concrete. The optimum percentage of recycled aggregate found from the comparative study was 25% for the ultimate strength and 50% for the ultimate density.

Goliya and Mahajan (2008) conducted research with the aim of identifying a suitable alternative for concrete ingredients. Cement is replaced by fly ash, stone dust, ground granulated blast-furnace slag and sand is replaced by stone dust and fly ash to find out the

strength properties such as compressive strength and flexural strength of concrete and this through a partial replacement of cement and sand by glass powder respectively.

Caiju and Keren (2006) conducted research on the utilization of recycled waste glasses in Portland cement and concrete has gained significant attention globally due to escalating disposal costs and environmental concern. Theoretically, finely ground glass exhibits pozzolanic or cementitious properties making it suitable as a cement replacement in concrete. While crushed glass aggregates can compromise concrete performance study show feasible applications with up to 100% aggregate replacement. However, the primary challenge lies in mitigating expansion and cracking caused by glass aggregates. This review consolidates existing research on waste glass utilization in Portland cement and concrete, identifying the best practices and future research directions.

Nathan and Narayanan (2008) researched on fine glass powder effects on cement hydration revealed its superior pozzolanicity compared to fly ash. The key findings indicated mineral alkali release, enhanced hydration and improved mechanical properties. A 5% cement replacement with glass powder was found effective. The study concluded that fine glass powders a viable supplementary cementing material improving durability properties. The research highlighted the importance of particle size on pozzolanicity and identified optimal replacement level paving the way for potential applications in sustainable construction.

Ahamed and Armin (2004) researched on post-consumer glass in concrete reveal its potential as a sustainable durable material. Fine glass powder (GLP) exhibits pozzolanic properties suppressing alkali-silica reaction. With up to 30% and reduced drying GLP replacement, concrete shows satisfactory strength and reduced drying shrinkage. This eco-friendly solution reduces landfill waste, substituting expensive materials like silica fume

and fly ash. Recycling post-consumer glass as GLP offers a valuable opportunity for sustainable construction enhancing concrete durability while minimizing environmental impact.

Achmad *et al.* (2016) investigated the potential of waste materials in soil stabilization. They found that by Incorporating cut waste plastic (HDPE) and crushed waste glass into high-plasticity clayey soils yield substantial improvements. This include reduced the liquid limit and plasticity index, increased optimum water content and maximum dry density and the enhanced California bearing ratio (CBR) value. Shear strength parameters also improved indicating enhance soil stability. By leveraging waste materials, the sustainable approach reduces disposal cost, minimizes environmental impact and optimizes pavement subgrade construction. By offering a viable solution for environmental conscious infrastructure development.

Kamali and Ghahremanimezhad (2016) investigated into the hydration and microstructure of cement pastes modified with glass powders. The research revealed that glass powder refines pores, exhibit pozzolanic behavior and improve reactivity due to their fine particle size and chemical composition. Compared to fly ash, GP1 demonstrated superior hydration ratio and microstructural improvements. The findings confirm glass powder with microscale size distribution as expective pozzolans suitable for incorporation into cement base to material promoting sustainable development and reducing waste and environmental impact.

Parviz (2012) investigated the effects of milled waste glass on recycled aggregate concrete have revealed enhanced strength, durability and microstructure partial replacement of cement with milled glass improves pore refinement, chemical resistance and moisture resistance driven by pozzolanic reactions. This eco-friendly approach mitigates recycled aggregate limitation, leveraging glass consistent chemical composition. The research

showed improve in compressive strength, increased in slump and refined microstructure. By incorporating milled waste glass, construction industries can reduce waste disposal promoting sustainable materials and develop durability concrete.

Roz- Ud-Din and Parviz (2012) studied showed the potential of milled waste glass as a partial cement replacement in reducing environmental and energy impact of cement base products. The study demonstrates the microscale milled glass waste glass undergoes pozzolanic reactions with cement hydrates enhancing structure and pore system characteristics. These reactions improve moisture resistance, chemical stability and microstructure while suppressing alkali-silica. Moreover, the preservation of cement pastes alkalinity ensures chemical stability and protect reinforcing steel. Collectively, these findings underscore the potential of milled waste glass as a viable and sustainable supplementary cementitious material.

Zhi *et al.* (2009) studied showed glass powder effects on lightweight aggregate concrete's strength, chloride permeability and alkali-aggregate reaction expansion. Glass powder slightly reduced short term strength but showed no long-term effects. It outperformed blast furnace slag and fly ash in improving chloride resistance and prevent deleterious expansion. In conclusion, glass powder enhances concrete durability, making it a viable sustainable material in construction.

Yaolin *et al.* (2015) research investigated the potential of reactive magnesia (MgO) and carbide slay (CS) activated ground granulated blast furnace slag (GGBS) for soil stabilization, benchmarked against Portland cement. The results showed that optimal MgO/CS activation from 10-20%. Significantly enhanced strength compressive strength. However, MgO-GGBS and CS-GGBS stabilized soils achieved 3.0-3.2 and 2.4-3.2 times higher 90 days UCS than PC stabilized soil. In conclusion, MgO and CS activated GGBS

offer superior soil stabilization performance, surpassing traditional PC methods with potential application so geotechnical engineering.

Seracettin and Omid (2015) research on soil stabilization for constructions on soft soils has showed toward polymer-based alternatives to traditional cement method. The study showed the efficiency of polymers (SACP, PVAC, xanthan gum) and fly ash in enhancing sand's unconfined compressive strength subjected to freeze thaw cycles. The result showed significant strength improvements with increased polymer ratios and curing times while freeze-thaw cycles had minimal impact. This suggest polymer-fly ash mixtures are a promising alternative for deep soil mixing application offering enhanced strength and durability and warranting further investigation.

Yuyou *et al.* (2013) investigated un cement soil durability in aggressive groundwater environments highlight the impact of environmental contamination on mechanical properties. The research has shown that acid conditions cause significant erosion, while alkaline conditions have minimal expects. Unconfined compressive strength increases with cement content and curing age through it a slower rate than regular cemented soil. Notably, strong and alkaline environments result in up to 30% strength loss. These finding underscore the importance of considering environmental factors in durability evaluation, residual life prediction and design for civil engineering.

Basha *et al.* (2005) researched on residual soil stabilization has explore chemical methods using cement and rice husk ash to enhance soil properties. The studies evaluated compaction, strength and X-ray diffraction whereby revealing reduced soil plasticity with cement and rice husk ash addition. However, maximum dry density decreased and optimum plasticity with cement and moisture content increased. Optimal stabilization was achieved with 6-8% cement and 10-15% rice husk ash, balancing plasticity, compaction, strength and consideration.

Muhammad *et al.* (2023) investigated into the use of waste glass as supplementary cementitious material in concrete have shown promising results. Partial replacement of cement from 10%-15% and fine aggregate from 15-20% with waste glass powder yielded reduced workability but optimal compressive strength and economy were achieved at 10% and 15% replacement level. Long-term curing enhanced strength developments, highlighting WGP pozzolanic properties. This sustainable approach reduces waste disposal concerns, conserves natural resources and maintains concrete mechanical integrity offering a viable solution for environmentally responsible building practices.

Mahbube *et al.* (2024) studied showed that self-compacting geopolymer concrete using waste glass as a partial sand replacement, following EN12620 guidelines and Australian standards. The results indicate that a 20% replacement of sand with glass particle yields an optimal 28-day compressive strength of 25 MPa, while higher replacements lead to a decline in strength. Optical microscopic analysis confirmed effective bonding between glass particles and the geopolymer matrix with variation noted as glass increased. In conclusion, incorporating waste glass at a 20% replacement enhances the mechanical properties of geopolymer concrete offering a sustainable alternative without compromising structural integrity.

Yusuf and Ali (2024) investigated into the performance of steel fibre reinforced concrete with sand substitution using waste glass revealed promising results. The study employed waste glass powder as a fine aggregate replacement at 0%, 10%, 20% and 30% volumes in C30 grade concrete, integrating 0.5% hooked and steel fibre and maintaining a water cement ratio of 0.5. After 28 days of curing period, the maximum compressive strength achieved was 32 N/mm² at 30% glass replacement, slightly surpassing that of conventional concrete. Additionally, the highest tensile strength of 3.90 N/mm² noted at a 20% replacement level, also exceeding normal concrete performance. The findings indicate that

optimal incorporation of waste glass enhances both the compressive and tensile strengths, making the approach a sustainable and environmentally friendly alternative for concrete production.

Sabbrojjaman *et al.* (2024) investigated into waste materials in concrete revealing their potential to mitigate environmental issues. The study compares the mechanical properties and durability of high-performance concrete using recycled fine aggregates from waste glass ceramic and rubber. The findings indicate that waste glass and ceramic enhance performance while waste rubber generally reduces it, through lower percentages can be effective. Optimal results are seen with up to 30% waste glass and 50% waste ceramic. In conclusion, incorporating these recycled materials offers a sustainable solution for concrete production supporting eco-friendly construction, practices and informing future research in green concrete development.

Alema *et al.* (2024) investigated the use of waste plastic and waste glass as partial replacement for fine aggregate in concrete to address solid waste management. Concrete mixes of grade C25 showed that 10% replacement with a 3% waste plastic to waste glass ratio increased the compressive strength by 12.55% at 7 days and 6.44% at 28 days, while a 20% replacement reduced strength. The flexural strength improved by 19.7%. but splitting tensile strength decreased slightly. In conclusion, incorporating those waste materials enhances certain mechanical properties of concrete particularly flexural strength but careful management of replacement levels is crucial for sustainability.

Manishankar *et al.* (2024) study examined the feasibility of using waste as a partial replacement for the fine aggregates in concrete targeting sustainability in the concrete industry. M20 concrete mixes were prepared with glass cullet replacement of 0%, 10% 20% and 30%. The findings indicated that replacing up to 30% of fine aggregate with glass

cullet in concrete production not only supports sustainable practices but also encourages the construction industry to adopt eco-friendly solutions.

Fadya *et al.* (2004) study investigated the use of waste glass cullet as partial substitute for fine aggregate in concrete production aiming to reduce waste and enhance sustainability. A total of 36 concrete cubes were produced with varying glass cullet replacement from 0%, 5%, 10%, 15%, 20% and 25% while maintaining consistent mix proportions. The results showed a gradual decrease in compressive strength with increasing glass content, although the concrete maintained acceptable strength characteristics. Notably, using waste glass reduced water absorption by 25% and decreased dry density by 1-10% compared to control specimens while also improving the aesthetic appearance of the concrete. In conclusion, waste glass can be effectively utilized as fine aggregate replacement in concrete achieving satisfactory strength and reduced density without compromising workability, thus contributing to more sustainable Construction practices.

Griff (2024) research examined the use of recycled waste glass as a substitute for sand, gravel and cement in concrete to mitigate carbon emissions from Portland cement production. Ground waste glass improves mechanical properties reduces water absorption and has optimal replacement levels of 10% to 30% enhancing workability and minimizing landfill waste. In conclusion, incorporating recycled glass in concrete provides a sustainable solution that boosts performance and supports eco-friendly construction practices.

Soran *et al.* (2024) research examined the use of waste glass granules as partial substitute for coarse aggregates in concrete, testing replacement ratios 5%, 10%, 20%, 30% and 50%. The result indicates the waste glass increases concrete density and impermeability while reducing water absorption. However, higher replacement ratio negatively affect compressive and flexural strength with an optimal level of 15% identified to minimize strength loss. In conclusion, while waste glass enhances certain properties and support

sustainability careful management of replacement level is essential to maintain structural integrity.

Chaupeng *et al.* (2004) studied showed the use of waste glass powder and waste glass aggregate in engineered cementitious composites (ECC) for sustainability. High waste glass powder volumes reduce compressive and flexural strength, while 100% WGP replacement enhances these properties. Up to 25% substitution of both materials improves strain capacity but 50% cement replacement with WGP significantly decreases strain capacity and ultimate tensile strength. Waste glass powder increases water permeable porosity. mix moderate WGA, reduced it. In conclusion, managing substitution levels is crucial to maintaining the performance of sustainable ECC made with glass.

Mokhar *et al.* (2024) investigated the use of glass waste as an alternative aggregate in promote sustainability. In the study, various percentage of crushed glass sand from 16% 20% 30% and 40% were added to reference concrete mixes. The results show that glass improves workability, reduces density and increase compressive strength up to 96% at a 20% substitution rate though challenges with density and adhesion persist at higher levels. In conclusion, incorporating waste glass as a substitute for natural sand in concrete provides significant benefits including improved workability and strength while supporting waste reduction and sustainable constructions practices.

Hariharan and Punitha (2024) studied showed that toughened glass waste as a coarse aggregate in high performance concrete to address glass waste disposal. TGW improves compressive and flexural strength and enhances durability, especially at moderate replacement level although excessive use may weaken the bond with the cement. In conclusion, using toughened glass waste concrete offers a sustainable solution while enhancing HPC properties.

Hassan and Pekrioglu - Balkir (2024) studied showed that using crushed waste glass as a partial sand replacement in cement mortar for sustainability. Mixed colored glass sand (MCGS) improved flow table values by 2.7% with 5% replacement and increased compressive strength by up to 60% at 15% replacement. Clear glass sand (CGS) also enhanced strength, with up to 5.45% compared to the control mix. In conclusion, incorporating waste glass in construction boosts mechanical properties, conserve resources and provide economic benefits promoting sustainable building practices.

Premathilaka *et al* (2024) investigate the use of recycled waste glass as a substitute for natural aggregates in construction, addressing the growing demand for aggregates and environmental concerns. AWG shows potential to enhance concrete performance but faces challenges like alkali-silica reactions and composition variability. In conclusion, using recycled waste glass offers a sustainable alternative to natural aggregates, reducing landfill waste and conserving resources through further research is needed for optimization.

Danish *et al.* (2021) investigated the geotechnical potential of crushed waste glass in comparison to naturally sourced sand and manufactured sand. CWG, derived from 100% recycled glass exhibited similar behavior to Ns and Ms in terms of gradation specific gravity and shear strength. Notably, CWG demonstrated superior permeability and abrasion resistance. Mineralogical analysis revealed silica dominance in all materials. Crushed waste glass emerges as a viable, eco-friendly alternative to traditional construction sands.

Sevket (2020) study the use of waste materials like marble dust and recycled glass sand in concrete production offers significant sustainability benefits while maintaining performance. Although RGS can reduce strength by 19%, MD shows initial strength less that recovers over time. Concrete's thermal and acoustic properties enhance energy efficiency and occupant comfort with CO₂ emissions largely driven by Portland cement

content. Economic analyses indicate that replacing Portland cement with marble dust can lower costs by up to 17.5%. Overall, while challenges remain in optimizing mechanical properties, integrating waste materials supports sustainable construction practices and warrants further research for improved outcomes.

Kavyateja *et al.* (2016) showed that using crushed glass as a replacement for fine aggregate in concrete production. In the work, the compressive strength of concrete increased with the use of glass up to 20% replacement level. The workability also increased with increasing the glass content, while the split tensile strength decreased with glass content. In conclusion, the study promoted the use of crushed glass as a sustainable and cost-effective alternative to sand in concrete production.

Karthik and Suresh (2024) studied examined the effect of replacing fine aggregate with glass waste particle on concrete properties. In the research, 135 specimens were cast, including cubes, cylinder and prism. Glass waste particles replaced fine aggregate from 0% to 40% in 10%. The test was conducted on 7th, 14th and 28th days to determine compressive split tensile and flexural strength. In the results, workability decreased with increasing GWP replacement, while compressive strength increased by 11.3% at 28 days with 30% GWP replacement. The flexural strength increased by 7.2% at 28 days with 30% GWP replacement. In conclusion, the study results contributed to the growing body of research on sustainable concrete production, highlighting the potential management cost.

Josmar and Josette (2012) investigated on the utilization of imploded glass in structural concrete. The research utilized mixed waste glass, crushed or imploded to replace up to 40% of Portland cement. The results showed that 40% replacement yielded concrete with adequate properties while 10-20% replacement exhibited high resistance to chloride ion penetration making it suitable for coastal structures. The implosion method produced sharper contaminant free particles improving ability. The findings suggest that

incorporating waste glass in concrete can reduce environment impacts and conserve resources, warranting further research into optimal replacement level and long-term effects.

Ashaya *et al.* (2009) stated that there is a need to find a new and alternative material to replace the river sand such that excess river erosion and harm to the environment is prevented. Many researchers are finding materials to replace sand and one of the major materials quarry stone dusts. Using different proportion of these quarry dust along with sand the required concrete mix can be obtained. This paper presents a review of the different alternatives to natural sand in preparation of mortar and concrete. The paper emphasizes on the physical and mechanical properties and strength aspect of a mortar concrete.

Zhi *et al.* (2004) studied showed glass powder effects on light weight aggregate concrete strength, chloride permeability and alkali. Aggregate reaction expansion-glass powder slightly reduced short term strength but no long-term effects. It outperformed blast furnace slag and fly ash in improving, chloride resistance and prevent deleterious expansion. In conclusion, glass powder enhances concrete durability making it a viable sustainable material in construction.

Md Nabi *et al.* (2020) studied highlight the potential of waste glass as a supplementary cementitious material and fine aggregate in concrete, although Comprehensive research is limited. The mechanical properties are influenced by factor like glass type particle, size and curing condition. In the experiment, they found that concrete with 10% glass powder and 10% broken glass exhibited a 9% reduction in strength compared to control specimen while improving economic viability. Overall, while the pozzolanic reactivity of waste glass is affected by its fineness and color. Further research is needed to explore its full potential in sustainable based construction.

Yubo *et al.* (2020) investigated the use of sustainable alternative to quartz sand in ultra-high-performance concrete and river sand in ultra-high-performance concrete and river Sand. Various Substitution ratios of GS were tested, revealing that the fluidity improved significantly and compressive strengths peaked at a 73% Sand replacement. However, Sand do not notably affect flexural or splitting tensile strengths. Acoustic emission analysis characterized fracture behaviors While across the concrete types, while scanning electron microscopy provided insights into microstructural changes. The findings underscore the potential of using recycled glass microscopy sustainable construction practices, particularly in bridge applications.

2.2 Glass aggregate in concrete and their effect on mechanical properties

Crushed waste glass has been the subject of numerous research and attempts in recent years to partially replace coarse and fine aggregates. In comparison to plain concrete, this study's findings included the use of broken waste glass in a proper manner, which gave them good abrasion resistance and reduced shrinkage in dry conditions. Additionally, compared to plain concrete, concrete containing waste glass has a lesser capacity to absorb water. (Unit for Concrete Technology, 2003).

A study by Jin *et al.* (2000) looked at using coloured glass aggregate to partially replace coarse and fine aggregate. The findings demonstrated that, in contrast to concrete with coloured waste glass, the concrete with non-coloured waste glass recoded a significant expansion brought on by the ASR reaction.

According to Meyer (2000), the inclusion of glass as aggregate will have an impact on the mechanical characteristics of concrete because glass aggregate and cement paste have a lower adhesion and bond strength because glass has comparatively smooth surfaces as opposed to natural aggregate's relatively rough surfaces.

In addition, Park (2004) reported that the use of waste glass as fine aggregate will decrease the slump value to observing that the mechanical properties (compressive, tensile, and flexural strength) of concrete containing waste glass as fine aggregate decreased with an increase in the replacement level of waste glass.

According to research by Corinaldesi *et al.* (2005), employing 30–70% waste glass as a fine aggregate in concrete has no negative macroscopic effects because of the reaction between cement paste and crushed waste glass with particle sizes up to 100 μm . The waste glass's beneficial contribution to the microstructural qualities, on the other hand, resulted in a noticeable improvement in the mortar's mechanical performance. With particle sizes up to 100 μm , no alkali-silica (ASR) reaction was found, indicating that waste glass can be utilized as fine aggregate in mortars and concrete.

Topçu and Canbaz (2004) observed that as the amount of waste glass added to concrete mixtures as coarse aggregate increased, the mechanical qualities of the concrete containing waste glass declined.

According to Shehata *et al.* (2005), the mechanical properties of concrete composites with waste glass used as a partial volume replacement of fine aggregate had greater modulus of rupture values for all glasscrete mixes when compared to reference mixes. The primary results of employing discarded glass as a fine aggregate are that the glass aggregates function as crack arrestors, stopping cracks from spreading through them, and that there is good interfacial bonding between the cement paste and glass aggregates.

For both structural and non-structural applications, Shayan (2002) noted that a mixture of coarse and fine glass aggregate could not be used in place of more than 50% by weight of the typical aggregate. To reduce the negative consequences of the alkali-silica reaction,

however, the right measures should be implemented, such as the use of appropriate pozzolanic materials in the right amounts.

According to Seung *et al.* (2004), the angular grain morphologies of waste glass caused the slump and compacting factor of concrete containing waste glass aggregates to decrease as the waste glass content increased. Additionally, the maximum mechanical property values are obtained from concrete that contains 30% waste glass as fine aggregate and 10% SBR.

According to Mohamad (2005), as temperatures rise to 700 °C, the compressive strength of concrete constructed from leftover glass might drop by as much as 20%. Concretes with 10% fine waste glass replacement in place of aggregates often performed better both in the fresh and hardened states at room temperature and at high temperatures than those with bigger replacement. At both room temperature and higher temperatures, concretes containing fine waste glass aggregates exhibited greater compressive strengths than those containing coarse waste glass aggregate.

Chen *et al.* (2006) found that using leftover E-glass to replace fine aggregate significantly improves mechanical qualities, especially compressive strength at later ages.

Terro (2006) examined how hardened characteristics changed at room temperature and at higher temperatures when discarded glass was used as fine and coarse aggregate. According to the results, the controlled mix's compressive strength decreased by 20% as the temperature rose to 700 °C. In both ambient and high temperatures, the concrete with 10% aggregate replacement had superior qualities.

Bashar *et al.* (2007) observed that the presence of particles recycled glass sand (RGS) can lower the permeability of the concrete and the amount of water in concrete was reduced when the content of (RGS) was raised. On the other hand, the presence of recycled glass

sand (RGS) in concrete will lower of the consistency of the cement paste and adhesive bond of the materials inside the concrete mix. Additionally, it was noted that adding recycled glass sand (RGS) to concrete lowers the workability and compaction factor when compared to a regulated mix, which will have a detrimental effect on the concrete's strength characteristics.

2.3 Summary

The majority of study, according to the review, concentrated on the use of wasted glass as fine aggregate in varying proportions and how it affected the mechanical qualities of concrete. The characteristics of concrete are negatively impacted when waste glass is added, according to several research. In other research, it was discovered that concrete qualities improved when a certain percentage of sand replacement, not to exceed 30%, was used. To find the ideal replacement percentage of waste glass without compromising the mechanical qualities of concrete, more study must be done.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter outlines the methodology and discusses the fundamental tests performed on materials used to cast concrete samples. A brief explanation of the mix design and chosen curing method follows. The experimental tests performed on the specimens are covered in this chapter.

3.2 Materials used

The materials used in this study include:

1. Cement
2. Coarse aggregate (granite)
3. Fine aggregate (sand)
4. Crushed waste glass (as fine aggregate replacement)
5. Water.

3.2.1 Cement

Ordinary Portland Cement (OPC) conforming to NIS: 1325.2015 was used in this study.

The cement was sourced from a reputable Local manufacturer.

3.2.2 Fine Aggregate

Natural River sand conforming to Nis: 1325.2015 was used as control fine aggregate. The sand was sourced from a local river bed and the fine aggregate was natural sand of 4.75 mm maximum size.

3.2.3 Pulverized Glass

Glass was collected from waste dump. It was then pulverized to a fine powder using an impact crusher and jet mills. The physical and chemical properties of the pulverized material were determined as per relevant Nigerian Standards.

3.2.4 Coarse Aggregate

Crushed granite aggregate Conforming to to NIS 132: 2015 was used. The maximum size of the aggregate used was 12mm

3.2.5 Water

Potable water was used for mixing gotten from tap in the civil engineering laboratory, University of Benin.

3.3 Mix Design

The Concrete mixes were designed based on the guidelines of NIS 494:2015. The control mix was designed for a target compressive strength of 20 N/mm² at 28 days. The control concrete mix ratio was 1:2:4 with cement (325 kg/m³), sand (650 kg/m³), gravel (1300 kg/m³), and water (195 kg/m³) for a water-cement ratio of 0.6 computed for 9 cubes. The pulverized glass was used as a partial replacement of fine aggregate ranging from 0%, 5%, 10% and 15%.

Table 3.1: Mix proportions

No	Mix	W/C	Cement (kg/m ³)	Coarse aggregate (kg/m ³)	Fine aggregate (kg/m ³)	Glass (kg/m ³)
1	Control mix	0.6	325	1300	650	0
2	5% Replacement	0.6	325	1300	617.5	32.5
3	10% Replacement	0.6	325	1300	585	65
4	15% Replacement	0.6	325	1300	552.5	97.5

3.4 Specimen Preparation

To stop concrete from sticking to the moulds, oil was applied to the moulds before they were ready for casting.

3.5 Specimen mixing, casting, and curing

0.1 m³ rotary type mixer was used for the mixing process. An electronic balance with great precision was used to weigh the materials. In the mixer, all of the materials are combined with the concrete for a minimum of three to four further minutes. Each combination was made in a clean, lubricated mould that was set on a vibrating table. For around 30 seconds, the samples were kept on the vibration table. For the first twenty-four hours, the samples were kept at room temperature in the mould. They were then carefully taken out of the mould, making sure that none of the edges were broken, and put in the curing tank to cure at room temperature.

3.6 Testing of specimens

Two types of testing were carried out: the fresh concrete test and the hardened concrete test.

3.6.1 Test on Fresh Concrete

The slump test was conducted on fresh concrete after the concrete mixing.

3.6.1.1 The Slump Test

The slump test is a widely used method to measure the workability of fresh concrete. The slump test assesses the concrete ability to flow and fill forms which is crucial for achieving the desired shape and finish. The slump cone is a metal cone with a height of 12 inches (300mm) and a base diameter of 8 inches (200mm). The tamping rod is a rod used to compact the concrete in the slump cone. The leveling rod is used to level the concrete in the slump cone.

3.6.1.1.1 Procedure

1. Prepare the concrete mx according to the Specified mix ratio.
2. Fill the slump cone with the fresh concrete in three layers each approximately 4 inches (100mm) high
3. Compact each layer using the tamping rod 25 strokes per layer
4. Level the top of the concrete using the leveling rod
5. Carefully left the slump cone, allowing the concrete to slump
6. Measure the distance from the original height of the concrete to the top of slumped concrete. This is the slump value.

By measuring the overall slump of the concrete, you can tell whether or not the water cement ratio is too high and whether a mix will have high workability or not. The main reason to perform this test is to ensure batches of the same concrete are of constant quality and strength. The more water is added to a mix the weaker the concrete gets. Depending on the water-cement ratio of the mix, the concrete slump will fall under one of these categories

True Slump: The Concrete largely retain the cone shape. demonstrating that mix is cohesive and its workability isn't too high.

Zero Slump: The Concrete retains its shape completely. This shows that the

Shear Slump: The top half of the concrete subsides dramatically leaning to one side the mix has workability but low cohesion. The mix may have too much water content and can be made retested after being amended.

Collapse Slump: The mix doesn't retain its shape at all and completely collapse. This means the water cement ratio is too high and needs to be fully amended.

3.6.2 Test on Hardened Concrete

For hardened concrete, compressive strength of testing was carried out. Just prior to testing, all specimens were removed from the water. At each test, the average of three specimens' results is used.

3.6.2.1 Compressive strength test

The compressive strength test was carried out according to (B.S 1610: part 1: 1992) and concrete specimens were cast in standard molds of size (100mm x 100mm x 100mm), for compressive strength tests. The molds were oiled internally to Facilitate easy removal of the specimens. Cube Specimens were tested at 7, 14 and 28 days of age using a compression testing machine conforming to NIS 1341, 2015. the compressive strength was calculated as the maximum load divided by the cross-sectional area of the specimen.

3.6.2.1.1 Testing Procedures

The Concrete will be made according to a specific mix ratio that is intended for both plain concrete and concrete with waste glass. Materials like cement fine aggregate, coarse aggregate and broken glass are accurately weighed.

3.6.2.1.2 Curing

After Casting, the specimens were cured in a moist chamber at a temperature of $21 \pm 2^{\circ}\text{C}$ and a relative humidity of $95\% \pm 5\%$ for 28 days.

3.6.2.1.3 Method of Testing in Cube Testing Method

The Specimens are examined 7, 14, and 28 days of age. The specimen to be tested can be taken out from water and wiped to remove excess water and grit present of the surface. The specimens are tested at specific ages for each type of mix. On compression testing machine with a 100-ton weight capacity cubes are positioned so that the marked face is facing the observer. Load is applied to the specimen and is increased at a rate of 140Kg per square centimeter per minute, until the specimen resistance to the increasing load is

destroyed and no more load can be sustained. Maximum load applied to the specimen to be recorded and compressive strength of the concrete is found out using the relation;

$$\text{Compressive Strength} = \frac{\mathbf{P}}{(\mathbf{B \times D})} \text{ N/mm}^2$$

P = Load in Newtons (N)

B = Breadth of cube in millimeters (mm)

D = Depth of cube in millimeters (mm)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results of the tests' outcomes and discussion of the results obtained. Concrete that had been both fresh and hardened was used for the testing.

4.2 Fresh Concrete Test

4.2.1 Slump Test

In Table 4.1, the slump test results are illustrated. When the waste glass ratio rises in comparison to the controlled mix, it is evident that the slump values decrease. For samples with 0%, 5%, 10%, and 15% waste glass, the slump values were 30, 34, 43 and 46 mm respectively, as illustrated in Figure 4.1. One possible explanation for this drop in slump values is the waste glass's poor geometry, which lowers the fineness modulus and reduces the fluidity of the mixes.

Table 4.1: Results of slump test

No	Mix	W/C	Slump (mm)
1	Control	0.6	30
2	5% Replacement	0.6	34
2	10% Replacement	0.6	43
3	15% Replacement	0.6	46

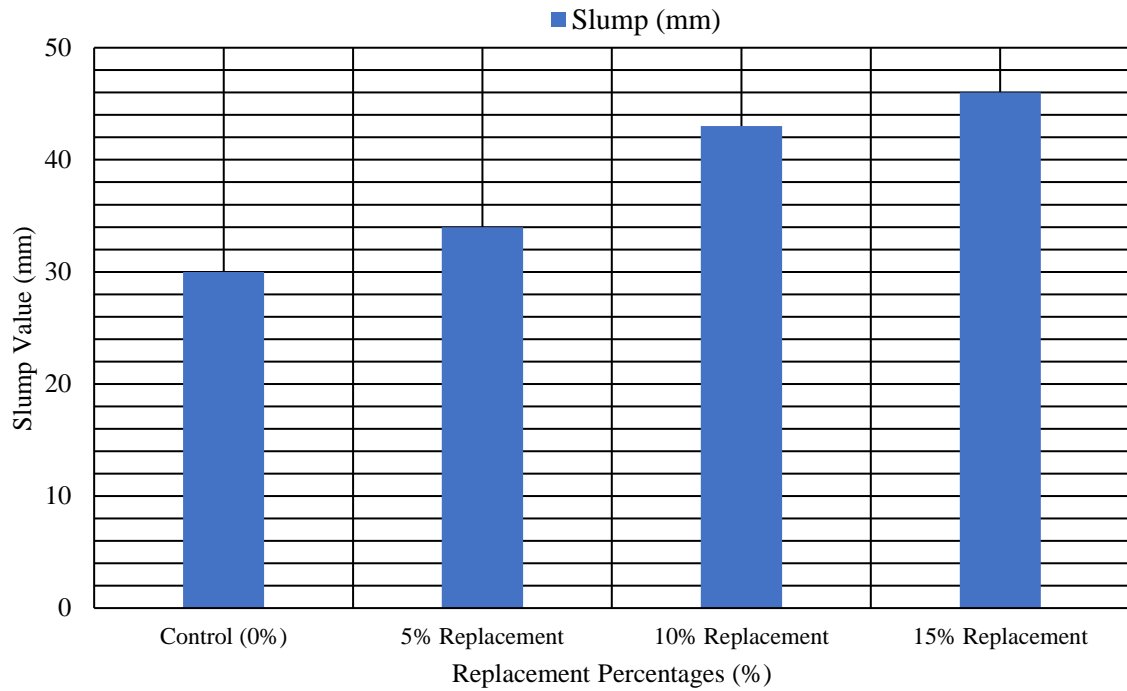


Figure 4.1: Result of slump value at varying % replacement

4.3 Hardened Concrete Result

4.3.1 Compressive Strength Test

In Table 4.2- 4.4, it shows the compressive strengths of the waste and controlled glass concrete mixtures at 7, 14, and 28 days respectively. Figure 4.2 displays a comparison of the compressive strength values for the identical blends. Figure 4.3 illustrates the evolution of compressive strength over time for controlled mixes and mixes that partially replace sand with glass aggregate at 5%, 10%, and 15%. It is evident that the concrete's compressive strength decreases when pulverized glass is added. According to the results, the concrete mix containing 5% waste glass fine aggregate gave the optimum 28-day compressive strength values. With age, the strength of all glass and controlled aggregate mixes increases steadily. It is evident that as glass aggregate replacement increases, the percentage increase in compressive strength with age generally increases as well. This demonstrates that when the pozzolanic effect became noticeable at a late age of 28 days.

Table 4.2: Average Compressive Strength Obtained after 7 days of Curing with Pulverized Glass replacement of 0%, 5%, 10%, and 15%.

Replacement %	Sample No	Weight (Kg)	Density (Kg/m³)	Failure load (KN)	Compressive Strength (N/mm²)	Average strength (N/mm²)
0%	1	2.643	2643	142.53	14.253	16.2027
	2	2.676	2676	199.82	19.982	
	3	2.621	2621	143.73	14.373	
5%	1	2.510	2510	176.57	17.657	15.452
	2	2.610	2610	142.67	14.267	
	3	2.685	2685	144.32	14.432	
10%	1	2.735	2735	113.22	11.322	14.7094
	2	2.736	2736	165.79	16.579	
	3	2.742	2742	162.273	16.2273	
15%	1	2.414	2414	158.82	15.882	14.3927
	2	2.447	2447	123.07	12.307	
	3	2.528	2528	149.89	14.989	

Table 4.3: Average Compressive Strength Obtained after 14 days of Curing with Pulverized Glass replacement of 0%, 5%, 10%, and 15%.

Replacement %	Sample No	Weight (Kg)	Density (Kg/m³)	Failure load (KN)	Compressive Strength (N/mm²)	Average strength (N/mm²)
0%	1	2.625	2625	162.43	16.243	18.2933
	2	2.585	2585	211.63	21.163	
	3	2.59	2590	174.74	17.474	
5%	1	2.631	2631	184.67	18.467	16.7477
	2	2.617	2617	181.93	18.193	
	3	2.603	2603	135.83	13.583	
10%	1	2.581	2581	169.35	16.935	15.801
	2	2.457	2457	163.46	16.346	
	3	2.571	2571	141.22	14.122	
15%	1	2.491	2491	162.27	16.227	15.2547
	2	2.486	2486	136.32	13.632	
	3	2.477	2477	159.05	15.905	

Table 4.4: Average Compressive Strength Obtained after 28 days of Curing with Pulverized Glass replacement of 0%, 5%, 10%, and 15%.

Replacement %	Sample No	Weight (Kg)	Density (Kg/m³)	Failure load (KN)	Compressive Strength (N/mm²)	Average strength (N/mm²)
0%	1	2.665	2665	190.35	19.035	20.675
	2	2.635	2635	230.01	23.001	
	3	2.677	2677	199.89	19.989	
5%	1	2.653	2653	200.8	20.08	19.722
	2	2.591	2591	199.85	19.985	
	3	2.596	2596	191.01	19.101	
10%	1	2.587	2587	155.86	15.586	16.2597
	2	2.565	2565	172.35	17.235	
	3	2.757	2757	159.58	15.958	
15%	1	2.651	2651	153.86	15.386	15.493
	2	2.673	2673	159.35	15.935	
	3	2.684	2684	151.58	15.158	

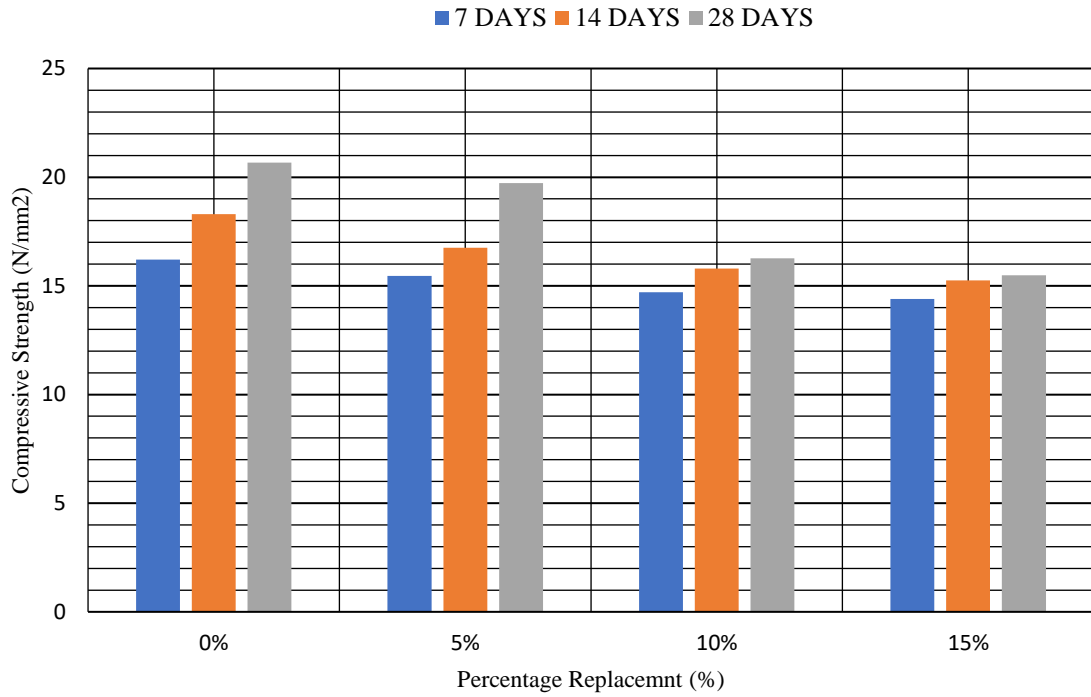


Figure 4.2: Chart showing comparison between the values of Average Compressive Strength for different glass aggregate replacements for three ages curing

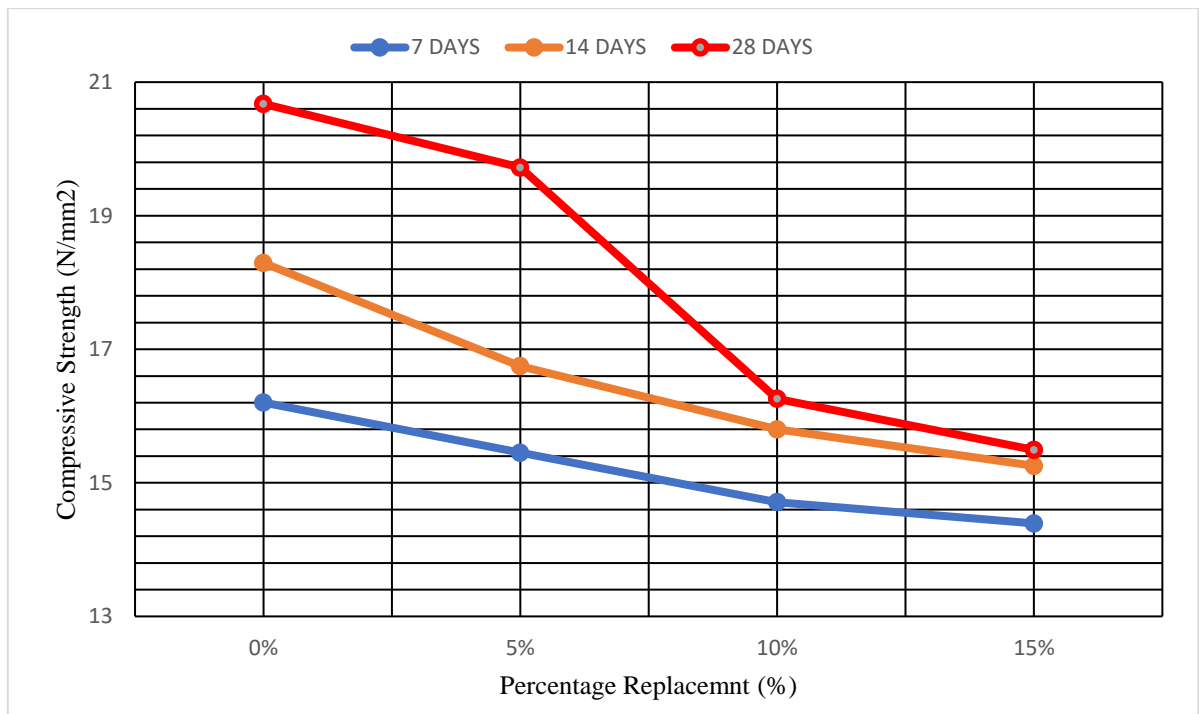


Figure 4.3: Graph showing Result comparison between the values of Average Compressive Strength for different glass aggregate replacements for three ages curing

4.4 Particle Size Distribution

4.4.1 Sieve Analysis

The sieve analysis results are presented in Table 4.5 and 4.6 for natural fine aggregates (sand) and pulverized glass respectively to determine their particle size distribution. The purpose of this analysis was to assess the suitability of pulverized glass as a partial replacement for fine aggregates in concrete. The results obtained from the sieve analysis, including the particle size distribution curves are discussed below.

Table 4.5: Result from Sieve Analysis for fine aggregate Total Mass of sand tested = 100.00g

SIEVE SIZE (MM)	MASS RETAINED (G)	PERCENTAGE RETAINED (%)	CUMULATIVE PERCENTAGE RETAINED (%)	PERCENTAGE PASSING (%)
2.36	0.30	1.26	0.11	96.21
2.00	0.15	0.15	2.71	94.22
1.18	2.26	6.627	9.408	90.59
600	19.28	31.66	41.068	58.93
425	6.68	18.96	41.068	58.93
300	10.73	22.92	82.948	17.05
212	21.90	12.05	94.998	5.00
150	3.95	0.69	95.688	4.31
75	3.97	1.52	97.208	2.79
Pan	1.25	0.269	95.477	1.5

$$\text{Retained\%} = \frac{\text{Mass retained Total}}{\text{Mass tested}} \times 100$$

Mass tested

Cumulative % Retained = % retained + the succeeding % retained

% passing = 100 - Cumulative % Retained % loss < 0.5

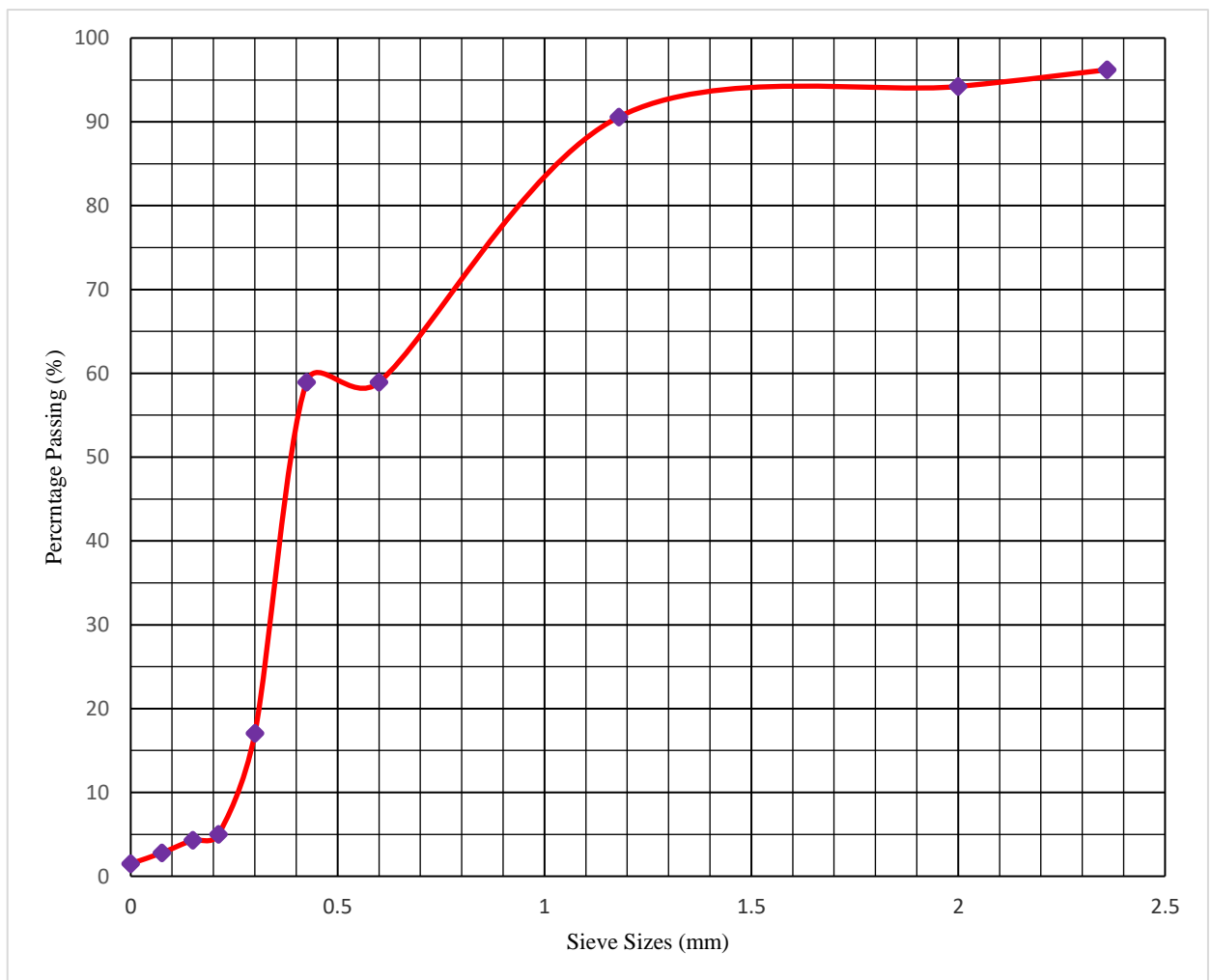


Figure 4.4: Graph showing fine aggregate variation of % passing with respect to different sieve size.

Table 4.6: Result from Sieve Analysis for Pulverized Glass aggregate Total Mass of sand tested = 100.00g

SIEVE SIZE (MM)	MASS RETAINED (G)	PERCENTAGE RETAINED (%)	CUMULATIVE PERCENTAGE RETAINED (%)	PERCENTAGE PASSING (%)
2.36	0.30	1.26	0.11	99.83
2.00	0.15	0.15	2.71	94.04
1.18	2.26	6.627	9.408	90.97
600	19.28	31.66	41.068	58.95
425	6.68	18.96	41.068	58.63
300	10.73	22.92	82.948	15.07
212	21.90	12.05	94.998	4.5
150	3.95	0.69	95.688	3.53
75	3.97	1.52	97.208	2.19
Pan	1.25	0.269	95.477	1.3

Retained% = $\frac{\text{Mass retained Total}}{\text{Mass tested}} \times 100$

Mass tested

Cumulative % Retained = % retained + the succeeding % retained

% passing = 100 - Cumulative % Retained % loss < 0.5

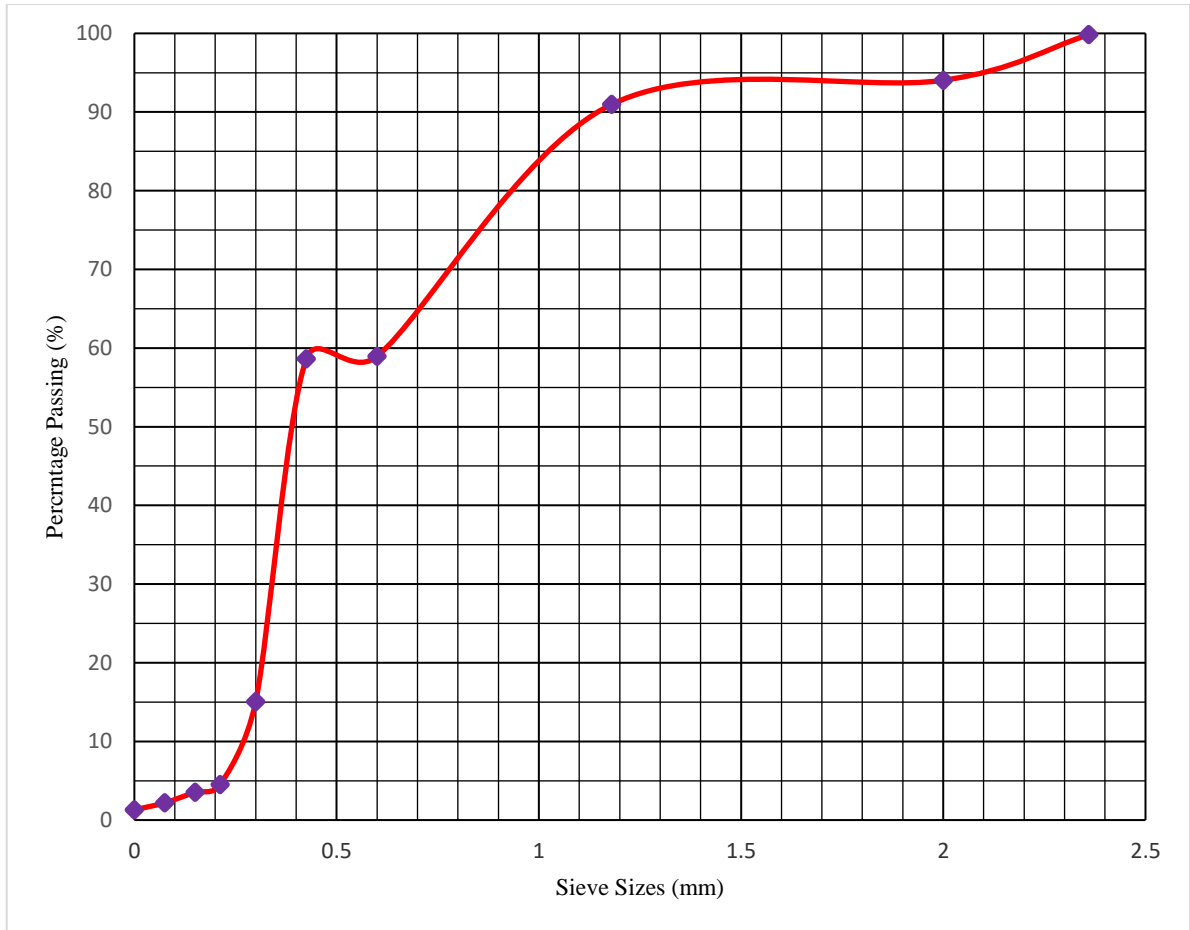


Figure 4.5: Graph showing glass aggregate variation of % passing with respect to different sieve size.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, this study aimed to explore the mechanical properties of concrete when pulverized glass is used as a partial substitute for fine aggregates. The investigation focused on evaluating the suitability, performance, and environmental benefits of using pulverized glass as an alternative material in concrete production.

Based on the findings from the experimental results obtained in chapter 4, the following conclusions were drawn that:

1. As the percentage replacement glass increased, the slump value of concrete decreased. However, concrete with glass aggregate have acceptable workability while having lower slump values. Comparing the 5%, 10%, and 15% substitution of natural fine aggregate to the control mix, the slump value decreases by 11.7%, 30.2%, and 34.8 respectively.
2. When finely crushed waste glass was used in place of some of the sand in concrete, the concrete's compressive strength decreased as the waste glass replacement percentage increased. At later ages, concrete that contains glass replacement exhibits lesser compressive strength.
3. At 28 days of age, the 5% replacement of finely ground waste glass with sand yields the optimum compressive strength compared to other percentage replacement.

5.2 Recommendations

This investigation was conducted by substituting waste glass for fine aggregate in concrete, with varying percentages of replacements. According to the results, 5% of waste glass sand should be substituted, since it demonstrated good compressive strength at 28 days of age. Suggestions are made to look at the long-term effects of waste glass on concrete durability. The recommendations are as follows.

1. Study of the long-term performance of concrete containing waste glass.
2. Study of the durability of concrete containing waste glass.
3. Study of the fire resistance of the concrete containing waste glass.
4. Investigate of the properties of concrete containing fine glass powder with size less than ($10\mu\text{m}$) as a cement replacement

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APPENDIX











